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SUBJECT: No. 1 ESS - Ways of Increasing Throughput of DAC Message Stores - Part I - Case 39215-2

DATE: December 30, 1963

FROM: L. E. Gallaher

MM-63-2423-8

ABSTRACT

This memorandum describes a method of queueing that is very useful for increasing the throughput to a sequential access memory. A method of using this technique is proposed for the No. 1 ESS Data Switching System Message Store. This technique makes it possible to meet the system requirements for the Message Store while using a single commercially available drum for each of the duplicated Message Stores.

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FROM: L. E. Gallaher
MM-63-2423-8

MEMORANDUM FOR FILE

Introduction

This memorandum is the first of two memoranda discussing various techniques for increasing the throughput of the Message Store for the Data Switching System. This memorandum covers the basic idea of queueing and how it applies to the Bryant Drums. The second memorandum discusses a queueing system for the Burroughs Disc File system.

DAC System Background

In order to better understand the requirements and needs of the Message Store, it is best to review very briefly the basic DAC system. DSEP #3 dated June 28, 1963, entitled "Extension of WADS to Use No. 1 ESS Office and to Provide New Service Features" established the system requirements for the DAC system while Department 2423 has mapped out the preliminary system and hardware requirements. Figure 1 shows a block diagram of the DAC system. The Buffer Call Store (BCS), Character Assembler-Disassembler (CAD), Message Store (MS) and Tape Control (TC) all are connected to a Buffer Control (BC), which is, in turn, connected to a

Central Control (CC), by means of the Call Store Bus. The CC ties to many other units much as in a No. 1 ESS office.

Normally, a message to be stored enters on one of the line terminals into the CAD. The message characters in turn will be moved to the Buffer Call Store to build a memory word of 2 characters and special flags as required. The memory words will be moved to a CS associated with CC for block assembly. Completed blocks are moved to the Buffer Call Store for delivery to the Message Store. The sending of a message is just the reverse of the previous process. Writing the tapes through the tape control is accomplished by reading the desired message from the MS back into the BCS and then to the TC so that the tapes are arranged by messages rather than by blocks.

The DSEP suggested that the DAC should be capable of handling 750 terminals of 100 wpm teletype at 100% line load. Real time limitations may limit the line handling capability to 700 lines at a peak load between 80% and 100%. The DSEP indicated that a multiple address factor of two should be designed for. That is, each message, on the average, must be delivered to two addresses. From the above, the data rate for message data to and from the MS can be calculated. However, since the data will be in block format, the size of the block and message length both become important. The DSEP

indicates that the average message length will be 200 teletype characters or 100 memory words. With heading included this should be increased to perhaps 250 characters. Figure 2 shows the per cent wastage expected as a function of block lengths. These curves do not allow for variations in message lengths about the average. Similar curves of wastage where variations in message length ~~was~~ were considered have been compiled by Department 2443.[1] In addition to block breakage, which causes the rise in wastage with block size on the right half of the chart, there is wastage due to chain linking which results in less wastage as the block size increases. The chain linking will probably use two words per block, one at the front of the block to identify the MS address of the block and one word at the end of the block to identify the address of the next block of the same message. From Figure 2 it would appear that a block size of 16 words would be the most desirable if the heading and text are stored separately. However, there are several other factors that must be considered. One of the most important factors for having larger size blocks is the throughput or rate of data flow to and from the MS. On most sequential access machines, the required time to gain access to a given block ~~is much longer than the given block~~ is much longer than the time required to transfer the data, once the data location is found. Thus for the block

1. ~~ESS~~ No. 1 ESS Data Switching System – Characterization of a Message Store – Case 39215-2, F. J. Fredericks, Nov 26, 1963.

sizes being considered, the throughput possible is essential proportional to the block size. Also longer blocks require smaller maps of MS block use status to be maintained in the call stores. On the other hand, large blocks have a disadvantage besides the high wastage. The size of the block assembly call store is directly related to the block size and ~~for~~ far outweighs the map storage requirements. The best balance of the above factors seems to favor a block size of 32 words and this size will be assumed throughout the remainder of this memorandum.

Drum Storage Background

Early studies by Department 2443 indicated that the drum storage system seemed the most suited for MS applica~~n~~tions except that its throughput fell short of system requirements. The drum provides a relatively inexpensive mass memory media that is non-volatile and, perhaps most important, is available within the time boundaries imposed on the DAC project.

The throughput is limited because it will, on the average, require one half revolution of the drum to obtain access to a particular block. Since some time is spent in data transfer, once the block is located, somewhat less than two block transfers per drum revolution should be expected. Several techniques are possible for increasing the throughput even with the above

restriction. For example, increasing the block size and increasing the drum speed both increase the throughput. However, increasing the block size increases the wastage (which, in turn, hurts the throughput) and increasing the drum speed has several disadvantages. First, the drive power increased rapidly as the speed increases; second, the mechanical reliability is decreased; third, drums having the desired capacity are not currently available in speeds higher than 1800 rpm.

Other methods such as multiple heads per track or multiple drums could be considered but only with an increased cost penalty.

Basic MS Data Requirements

The requirements below are based on the assumptions discussed under the DAC System Background and repeated in Appendix 1 with calculations for reference.

Throughput - The throughput requirements for the MS are shown in Table I. This table gives the throughput in block transfers per sec. as a function of the office load factor. Also given is the BTR (Block Transfer Rate) for an 1800 rpm drum. Assuming a maximum office loading of 0.9 and the message heading and text stored separately, about 180 block transfers per sec. or a BTR of 6 for an 1800 rpm drum is required to meet the system needs.

It is of interest to note that a 3600 rpm drum with a block size of 64 words would come very close to meeting the system throughput requirements. Such a drum could, on a random basis, access 2 blocks per revolution or 120 sixty-four word blocks per second. This is equivalent to about 200 thirty-two word blocks per sec. when the extra wastage of the larger block size is considered. Unfortunately the available 3600 rpm drums fall short on storage requirements.

Total Storage - The total storage requirement is a somewhat more nebulous number than that for throughput. Here total storage is taken to be the bits which can be transferred to or from the drum including wastage as previously discussed. Not included are guard bits or drum control bits such as found in clock and address channels on the drum. It can be shown that about 2×10^6 bits of storage are needed per minute of holding time. The holding time is primarily a function of the loading factor of the office. Assuming all messages are held until completely delivered and an average message length of 250 characters, the holding time is about 3.5 minutes for a .8 loading factor and about 6 minutes for a .9 loading factor. From this it would appear that 12×10^6 bits would be sufficient.

However, since many messages cannot be sent until they are entirely received due to an upward speed conversion, an extra penalty may be paid for long messages. This is of particular importance in considering interoffice traffic which probably will be accomplished with high speed data links. This, therefore, requires that nearly all interoffice traffic (between DAC offices) will require an upward speed shift and hence an increased storage capacity. For example, a half hour message generated by one 100 word per minute line and addressed to only one receiver with a higher speed line may effectively tie up more than 1/4 million bits of memory for periods varying from 20 to 60 minutes or more depending on the receiver speed and availability.

To allow for the increased requirements resulting from upward speed shifts and large message sizes, the over-all storage requirement is increased to approximately 20×10^6 bits.

Message Store Queueing

Queueing is a method of circumventing the necessity of using the drum in a random access mode of operation. Instead of searching for a particular block of information, a hunt is made for n blocks of information where these n blocks have been ordered in a list or queue corresponding to the order in which these blocks will be available from the drum.

Obviously if the list is large enough and properly ordered, the drum could be kept continually in use transferring data with no access time. Actually the operation of an endless queue can be performed by utilizing two queues, one of which is being used to address the drum while the other is being prepared by the data processor. The ~~later~~ latter list would be organized such that the first order (address) would follow immediately behind the last order of the previous list. When the first queue is completed the drum performs the work requested in the second queue and the first queue is reloaded with additional work.

The throughput is thus no longer limited to two per revolution but more nearly approaches the number of blocks on a track of the drum. In systems where the bits are written serially on a given track, the number of blocks per revolution is limited by bit densities and block sizes to numbers under 50 for present drums. This number could be greatly increased if the data were written in parallel or a form of series parallel combination. Since the data of a block would then be spread over more than one track, then the number of blocks available in a revolution would also be increased. Since the DAC system needs about 6 block transfers per revolution, the simpler serial mode of operation will be assumed.

Queueing with the Bryant Drum for DAC

Queueing is ideally suited to the DAC System. A work list of blocks to be transferred can be readily obtained from the overflow block information contained in one of the Central Control Call Stores and, for the case of reading from the drum, from the blocks assigned in the Central Control Call Store to receive information from the drum. This list would probably consist of a time ordered push-down list. From this list, the queues can be derived. The queue and the associated blocks could be placed in the BCS~~C~~ (Buffer Call Store) which has ample room for a reasonable sized queueing structure since the CAD is expected to use only about 25% of the BCS capacity.

The Bryant drum being considered for MS use is an 18.5" diameter, 1800 rpm drum with 1024 data heads and tracks. The capacity of this drum is in the range of 16×10^6 to 32×10^6 bits depending on the bit density that can be obtained and used in a reasonable manner.

The storage density (and storage capacity) is partly controlled by the data rate available between the BCS and the MS. The data transfer rate is limited by the data bus which connects the BC, TC, MS and BCS together. Basically it is a matter of time sharing the BCS among the units mentioned plus

CC and the CAD on a priority basis. Department 2443 studies indicated that MS could use the bus no more than once every five or six 5.5 μsec cycles with lower usage desirable.

System Proposal One

Assuming a maximum usage of 1 cycle in 6 for the MS and serial block format on the Bryant drum, the following system was proposed by Department 2423.

The drum would be operated at 1800 rpm ± 5% with twenty-eight data blocks on each track. Two queues of 8 instructions each would be utilized in the BCS. In this mode of operation it did not seem feasible to obtain access to adjacent blocks on the drum for two reasons. First, some time is necessary to read the queue instructions and this preferably is not done until data transfer is completed on the block being processed; also time is required after head selection operations to allow switching transients to decay sufficiently to make reading the drum possible. With this in mind and thinking of the blocks as being numbered sequentially around the drum, it was proposed to make one queue for even blocks only and one queue for odd numbered blocks. At first glance this seems inefficient. It is, in fact, not as efficient when only a small work load is given the drum. Fortunately it reduces to essentially the same

efficiency as could be obtained without the odd-even queue restrictions at high load conditions. High load is assumed here when the push-down list has more than 28 entries, the total number of data blocks per ~~trunk.~~ track.

The lengths of the queues do not affect the system throughput as long as the system can fill the queues faster than the drum can process the orders. However, when the system is lightly loaded it is necessary to provide some means of preventing the MS from transferring rapidly from one queue to the other looking for work and possibly interfering with loading the queue. To aid this operation, each of the 8 orders comprising a queue must result in some minimum real time usage of the drum; that is, when there is insufficient work to fill a queue with work orders, the queue will be filled as necessary with no-op (no operation required) orders that will cause the drum to do nothing but mark time for a period equal to two block transfer times. Thus the drum will spend a minimum time of 19 msec processing either queue. This gives CC sufficient time to prepare one queue while the drum is working on the other.

The queue as proposed might appear as in Figure 3, showing the even and odd queue as stored in the BCS. Each queue order consists of two BCS words. One word contains the MS block concerned in the data transfer, while the second word contains the BCS address of the beginning of the data block plus suitable instructions indicating the direction of desired data transfer. The second word also provides space for the MS to write a status report back into BCS upon completing a block transfer.

An interesting feature of this operating mode is that its efficiency increases with the work load and with the size sample taken from the push-down list to derive the queues. Figure 4 is a plot of the block transfers per revolution possible plotted against the size of the work list from which the queues are derived. The probability calculations for this curve are discussed in Appendix 2. From the curve it can be seen that if 32 items were available for transfer, we should on the average be able to transfer 9.6 blocks on each of the next two revolutions. Of more importance is the number of items that will have to exist in the work list to maintain an average of 6 transfers per revolution of the drum as required by the system. This number can be seen to be about 17. This states that during high loading on the office the push-down list should average about 17 items.

The actual push-down list should have a much larger capacity to allow for peaking and special functions such as drum maintenance. It may be desirable to do maintenance operation on the drum for one or several revolutions of the drum. This, of course, means that the allowable length of the push-down list will probably exceed 100. In order to recover from peaks or maintenance interruptions it will be necessary to transfer more than ~~5~~ 6 blocks per revolution. It is therefore suggested that the bottom 32 items of the push-down list be scanned for possible use in the queues during the next two revolutions of the drum. Then, as mentioned before, the block transfer rate should be 9.6 blocks per revolution which should rapidly reduce the push-down list to the balance level of about ~~14~~ 17 items.

This proposal also gives sufficient total storage to meet the system's requirements. The total storage is 29,672 data blocks or about 22-3/4 million bits.

<u>System Proposal Two</u>

System proposal two differs from proposal one in two ways. First, rather than 28 blocks per ~~trunk~~ track sequentially around the drum, that 32 blocks be placed in each ~~trunk~~ track with the words of block 0 and block 1 interleaved, the words of block 2 and block 3 interleaved etc. In addition between each

pair of blocks a space would be left on the drum corresponding to about 225 μsec to allow the MS to interrogate the queue in the BCS. This system would allow data to be transferred to any of the 16 even queues in one revolution and any of the 16 odd queues in the following revolution. This provides several advantages to the system. The interleaving of the words lowers the maximum bus usage from one cycle in six ~~6~~ cycles (proposal one) to one cycle in ~~out of~~ ten. The throughput is increased ~~147.~~ 14%. Because of the increase in the number of blocks per track ~~trunk~~ which, of course, also increases the total storage to about 25 x 10^6 bits. Also, the rather ~~other~~ awkward number 28 is replaced by a binary number 32 which improves the efficiency of the data handling process.

The second part of proposal two is the use a dedicated queueing structure and was suggested by Department 2443. This proposal would use two queues of 16 rather than two queues of eight with each of the 32 queue words having a one to one correspondence with the 32 block positions around the periphery of the drum. Thus even queue word 0 is always an order for the Block 0 position on the drum etc. This system reduces the number of bits required in the queueing instruction since the MS knows when it interrogates a queue, the block position involved on the drum. It need only obtain the track ~~trunk~~ address and mode of

operation. This allows each queue order to contain only one word rather than two used in proposal one since the four bit saved appear to be sufficient for use as a status report.

Proposal two increases the throughput as seen by Figure 5. With 32 items considered from a work list the block transfer rate is 10.2 blocks per revolution. The calculations are included in Appendix 2.

Although this proposal seems very desirable it does increase the bit density and bit frequency requirement on the drum. The bit frequency is increased from approximately ~~from~~ 725 KC to 950 KC. At this time, this appears to be ~~the~~ possible and therefore the use of this system proposal is contemplated.

Other Uses Of Message Queueing

The form of queueing discussed in this memorandum is applicable to all forms of sequential access memories. It is, however, practical only when the time required to switch from one track or channel to another is small (equal or less than the time required to transfer a block). Thus the system is well suited to drum memories and delay line memories where a read and/or write head is assigned to each track or channel.

This system is not easily adapted to most disc systems (the Burroughs disc file is an exception as it has a fixed head per track). Most disc files have mechanical head positioning systems with positioning times in the order of 100 µsecs even for small position changes. Since no data can be transferred during the positioning time it is desirable to again have a queue list to perform as many transfers as possible at each head position. However, if the data list is random in nature, the length of the list would have to contain several thousand orders to meet the data transfer rate required for the DAC system. For example, the Bryant Disc File which has 128 positions for each head and a rotational speed of 1200 rpm would require that 5000 items be scanned to just meet the system's requirements with no margins. Multiple positioning systems can cut this number by only two. The list could also be reduced by using a disc file with fewer head positions. The 5000 items mentioned above would be costly in both processing time and storage requirements, the latter since one-fourth of the 5000 could be expected to be overflow blocks, each containing 32 words or a total of 40,000 words. This would fill 5 call stores plus their duplicates.

Summary

In this memorandum the basic concept of queueing has been presented as it applies to increasing the throughput of a

sequential access memory. In particular, the queueing concept is applied to the DAC Message Store. The simple queueing system allows presently available drums to be used while fulfilling the DAC system~~s~~ requirements with confortable throughput margins. Without queueing, the system requirements could not ~~be~~ have been met unless many smaller high speed drums were used and then no throughput margin could ~~be~~ have been provided.

HO-2423-LEG-CS

Att - Appendices 1 and 2
Tables I and II
Figures 1 thru 7

Appendix 1

Throughput Requirements:

The throughput calculations are based on the following assumptions.

1. 700 terminals of 100 wpm half duplex teletype.
2. A multiple address factor of 2.
3. Two teletype characters per MS word.
4. Each block contains 32 MS words.
5. Per cent Block Wastage for heading and text stored together - ~~98~~ 18%. Heading and text stored separately - 27%.
6. Every input message is also transferred to tape. Therefore each active line has a data rate of 600 characters/minute or 5 MS words per second. The throughput in block transfers per second (BTs) can be calculated from the equation below.

$$\text{BTs} = \frac{\text{N of lines X L.F. X MS words/line/sec X } 4/3}{\text{Words per Block X } \left(1 - \frac{\text{\% Wastage}}{100}\right)}$$

where L.F. is the load factor or fraction of total lines in an active status.

Using the numbers previously specified the equation becomes:

$$\text{BTs} = \frac{700 \text{ X L.F. X } 5 \text{ X } 4/3}{32 \text{ X } \left(1 - \frac{\text{\% Wastage}}{100}\right)}$$

The results of this calculation are included in Table 1 for various values of L.F. and for heading stored with text and stored separately from text. Also shown in Table 1 ~~is~~ are the block transfers per revolution (BTR) assuming an 1800 rpm drum for message storage.

Appendix 2

This appendix is a discussion of the method used to calculate the values for Figures 4 and 5, which plot the average number of block transfer per drum revolution (BTR) as a function of the number of entries in the push down work list considered for filling the queues.

The method for computing the data for Figure 5 (System Proposal two) will be covered first since the method used to compute data for the System Proposal one is merely an extension of that used for ~~Systems~~ System Proposal two.

System Proposal two calculations

In calculated BTR for system proposal two the following assumptions were made.

1. The number of data ~~trunks~~ tracks (1024) on the Bryant Drum is sufficiently large to reduce the probability problem to a sorting problem with replacement. That is, the pro bability that a work entry in the push-down list requires work from a particular block number around the drum, is not affected by the contents (block number) of other work entries within the push-down list.

2. The program is arranged so that the information to fill both queues is calculated at the same time. That is, the data processor will examine the bottom "C" entries of the work list and attempt to obtain the data for both the even and odd queues. This operation would be performed once every two revolutions of the drum. The data for one queue could normally be transferred immediately to the Buffer Call Store (BCS) and the data for the other queue transferred to the BCS at the beginning of the next revolution.

If the data for the odd and even queues are calculated at separate times with each calculation drawing from "C" entries, then a slightly higher BTR rate will be obtained for some values of "C."

The method of calculating BTR as a function of "C" is given below.

$$BTR = 1/2\ B \times P\ (n;c,B) \text{ for } n > 0 \qquad (1)$$

where

BTR is the average number of blocks transfers per revolution.

c is the number of entries in the push-down list considered for filling the queues.

b is the number of blocks per ~~trunk~~ track around the drum.

n is the number of entries for a particular block number.

P(n;c,B) is the probability of n entries for a given block number around the drum as a function of c and B.

$$P(n;c,B) = 1 - P\ (0;c,B) \text{ for } n > 0 \qquad (2)$$

In general

$$P(n;c,B) = \frac{C(c,n) \times (B-1)^{c-n}}{B^c} \qquad (3)$$

where

C(c,n) is the number of ways of having n entries for a particular block number.

$(B-1)^{c-n}$ is the number of ways of spreading the c-n entries among the other blocks.

B^c is the total number of ways in which c entries can be distributed among B blocks.

However, for the special case of n=0.

$$P(0;c,B) = \frac{C(c,0) \times (B-1)^c}{B^c}$$

$$= \frac{B-1^c}{B^c} \qquad (4)$$

Therefore, combining equations (1), (2), and (4) yields

$$BTR = 1/2\ B \times \frac{(B-1)^c}{B^c} \qquad (5)$$

For 32 words per block equation 5 becomes

$$BTR = 16 \times \left(\frac{31}{32}\right)^c. \qquad (6)$$

This can be ~~best~~ calculated for various values of c by using logarithms, or by rewriting the equation and using the binominal expansion on equation (7) below.

$$BTR = 16 \left(\frac{32-1}{32}\right)^c$$
$$= 16 \left(1-\frac{1}{32}\right)^c \qquad (7)$$

System Proposal One Calculations

In this proposal the time to enpty a queue is not necessarily equal to one revolution as it is in proposal two. However, the probability calculations, in the previous section, are also valid for proposal one if properly interpreted. Equation (5) of the last section gave a general expression for BTR. The actual value being calculated in equation 5 is the average number of queue orders per queue that can be filled from "C" entries in the work list. In system proposal two the value for BTR is the same as the average number of queue orders per queue. Since this is not true for

system proposal one the equation is rewritten below to apply to proposal one.

$$M = B \times \frac{(B-1)^C}{B^C} \tag{8}$$

where M is the average number of queue~~s~~ entries available from "C" entries in the work list. The values for M with B = 28 are plotted as Figure 6.

To calculate BTR from M it is necessary to calculate the average number of revolutions to empty a queue as a function of M. This again is a probability problem and was worked out assuming that the data for both queues is calculated at one time. Thus the problem resolves to one of finding the number of revolutions required to empty both queues with the proper weighting factors applied to each of the perm~~en~~utations that can occur with the value M divided between the two queues. Table 2 lists the number of revolutions required to empty a queue as a function of ~~the~~ P, the number of orders in the queue. The values for table 2 are calculated ~~for~~ From the following equations.

$$\text{Revolutions} = \cancel{1-\frac{1}{2P} + \frac{1}{28} + \frac{8-P}{14}} \tag{9}$$

$$1-\frac{1}{2P}+\frac{1}{28}+\frac{8-P}{14}$$

The first three terms of the equation determine the average number of revolutions to locate and process P orders, the last term is the number of revolutions required to "No op" the remainder of the queue assuming, as previously discussed, that 2 block transfer periods are wasted for each "No Op" instruction in the queue. Figure 7 plots the average number of revolutions to empty M orders divided among the two queues. Figure 4 then plots the values of BTR for system proposal one. Figure 4 is plotted by first finding the value of M for a given value c, then finding the average number of revolutions to empty M orders from Figure 7 where

$$BTR = \frac{M}{\text{average number of revolutions to empty 2 M}}$$

$$BTR = \frac{M}{\text{average}}$$

TABLE I

Block Transfer Requirements For No. 1 ESS DAC Message Store

Assumptions

1. 700 terminals of 100 wpm half duplex teletype.
2. A multiple address factor of 2.
3. Two teletype characters per MS word.
4. Each block contains 32 MS words.
5. A block wastage of 18% for heading and text stored together and 27% for heading and text stored separately.
6. Every input message transferred to tape.

Load Factor	.8		.9		1.0	
Heading and Text Stored together (T) Separately (S)	T	S	T	S	T	S
Block Transfers per sec.	142	160	159	179	177	200
Block Transfers per revolution at 1800 rpm	4.74	5.33	5.30	5.96	5.90	6.67

TABLE II

Number of Drum Revolutions required to empty a queue as a function of P, the number of orders assigned to a queue.

P	Number of Revolutions
0	0.57
1	1.03
2	1.21
3	1.22
4	1.19
5	1.15
6	1.10
7	1.04
8	.97
9*	.98
10*	.98
11*	.99
12*	.99
13*	1.00
14*	1.00

*Indicates that order would be entered in a subsequent filling of the queue along with other entries.

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SUBJECT: Corrected Appendix 2 of Technical Memorandum MM-63-2423-8 dated December 30, 1963 by L. E. Gallaher - No. 1 ESS - Ways of Increasing Throughput of DAC Message Stores - Part I - Case 39215-2

DATE:

FROM: L. E. Gallaher

Attached is a corrected copy of Appendix 2 which should be inserted in place of the original Appendix 2. Equations (5) through (8) were incorrectly transcribed from the original work.

The results and curves in the original memorandum are correct and compatible with the corrected appendix.

L. E. Gallaher

HO-2423-LEG-VM

L. E. GALLAHER

Att.
Corrected Appendix 2
of MM-63-2423-8

APPENDIX 2

This appendix is a discussion of the method used to calculate the values for Figures 4 and 5, which plot the average number of block transfer per drum revolution (BTR) as a function of the number of entries in the push-down work list considered for filling the queues.

The method for computing the data for Figure 5 (System Proposal two) will be covered first since the method used to compute data for the System Proposal one is merely an extension of that used for System Proposal two.

System Proposal two calculations.

In calculating BTR for system proposal two the following assumptions were made.

1. The number of data tracks (1024) on the Bryant Drum is sufficiently large to reduce the probability problem to a sorting problem with replacement. That is, the probability that a work entry in the push-down list requires work from a particular block number around the drum, is not affected by the contents (block number) of other work entries within the push-down list.

2. The program is arranged so that the information to fill both queues is calculated at the same time. That is, the data processor will examine the bottom "c" entries of the work list and attempt to obtain the data for both the even and odd queues. This operation would be performed once every two revolutions of the drum. The data for one queue could normally be transferred immediately to the Buffer Call Store (BCS) and the data for the other queue transferred to the BCS at the beginning of the next revolution.

If the data for the odd and even queues are calculated at separate times with each calculation drawing from "c" entries, then a slightly higher BTR rate will be obtained for some values of "c."

The method of calculating BTR as a function of "c" is given below.

$$BTR = 1/2\ B \times \sum_{n=1}^{c} P\ (n;c,B) \qquad (1)$$

where

BTR is the average number of block transfers per revolution.

c is the number of entries in the push-down list considered for filling the queues.

B is the number of blocks per track around the drum.

n is the number of entries for a particular block number.

P (n;c,B) is the probability of n entries for a given block number around the drum as a function of c and B.

$$\sum_{n=1}^{c} P(n;c,B) = 1 - P(0;c,B) \qquad (2)$$

In general

$$P(n;c,B) = \frac{C(c,n) \times (B-1)^{c-n}}{B^c} \qquad (3)$$

where

C(c,n) is the number of ways of having n entries for a particular block number.

$(B-1)^{c-n}$ is the number of ways of spreading the c-n entries among the other blocks.

B^c is the total number of ways in which c entries can be distributed among B blocks.

However, for the special case of n = 0.

$$P(0;c,B) = \frac{C(c,0) \times (B-1)^c}{B^c}$$

$$= \frac{(B-1)^c}{B^c} \qquad (4)$$

Therefore, combining equations (1), (2), and (4) yields

$$BTR = 1/2\ B\left[1 - \frac{(B-1)^c}{B^c}\right] \qquad (5)$$

For 32 words per block equation (5) becomes

$$\mathrm{BTR} = 16\left[1 - \left(\frac{31}{32}\right)^{c}\right] \tag{6}$$

This can be calculated for various values of c by using logarithms or by rewriting the equation and using the binominal expansion on equation (7) below.

$$\mathrm{BTR} = 16\left[1 - \left(\frac{32-1}{32}\right)^{c}\right]$$

$$= 16\left[1 - \left(1-\frac{1}{32}\right)^{c}\right] \tag{7}$$

System Proposal One Calculations

In this proposal the time to empty a queue is not necessarily equal to one revolution as it is in proposal two. However, the probability calculations in the previous section are also valid for proposal one if properly interpreted. Equation (5) of the last section gave a general expression for BTR. The actual value being calculated in equation (5) is the average number of queue orders per queue that can be filled from "c" entries in the work list. In system proposal two the value for BTR is the same as the average number of queue orders per queue. Since this is not true for system proposal one the equation is rewritten below to apply to proposal one.

$$M = B\left[1 - \frac{(B-1)^{c}}{B^{c}}\right] \tag{8}$$

where M is the average number of queue entries available from "c" entries in the work list. The values for M with B = 28 are plotted as Figure 6.

To calculate BTR from M it is necessary to calculate the average number of revolutions to empty a queue as a function of M. This again is a probability problem and was worked out assuming that the data for both queues is calculated at one time. Thus the problem resolves to one of finding the number of revolutions required to empty both queues with the proper weighting factors

applied to each of the permutations that can occur with the value M divided between the two queues. Table 2 lists the number of revolutions required to empty a queue as a function of P, the number of orders in the queue. The values for Table 2 are calculated from the following equations.

$$\text{Revolutions} = 1 - \frac{1}{2P} + \frac{1}{28} + \frac{8-P}{14} \tag{9}$$

The first three terms of the equation determine the average number of revolutions to locate and process P orders, the last term is the number of revolutions required to "No op" the remainder of the queue assuming, as previously discussed, that 2 block transfer periods are wasted for each "No op" instruction in the queue.* Figure 7 plots the average number of revolutions to empty M orders divided among the two queues. Figure 4 then plots the values of BTR for system proposal one. Figure 4 is plotted by first finding the value of M for a given value c, then finding the average number of revolutions to empty M orders from Figure 7 where

$$\text{BTR} = \frac{M}{\text{average number of revolutions to empty 2M}}$$

*for $P \geq$ the fourth term vanishes

2CD.

No. 1 ESS - Data Administration Center -
Message Store Queueing - Case 39215-2
and 200513

FEB 11 1964

H. W. Ketchledge

MR. J. W. FALK (2):

A patentability study is requested for the queueing concept developed by Lee E. Gallaher of Department 2423. The work case on DAC is 39215-25.

Objective:

To increase the data throughput of a sequential memory.

Description:

Normally, the time required to gain access to a particular piece or block of data in a sequential access memory limits the throughput or rate of transfer from the memory. Thus if data with random addresses are requested from the memory, normally an average of only two or fewer data transfers can be obtained per memory period. A memory period is the time between two consecutive accesses of the same data bit. Thus for a drum with one head per track the memory period is the time for one revolution of the drum.

Queueing is used to organize the data transfer requests so that many units or blocks of data can be transferred to or from the memory unit in each memory period. Use is made of a buffer memory to hold the queue or work list that has been organized by a sorting process so that the orders in the queue or queues are arranged in the same order in which they become available in the sequential memory.

This is particularly useful in the case of a drum or disc memory having one head per track using block storage techniques. By arranging the block assignment so blocks on all tracks or groups of tracks start at the same time, then the queue list need only be ordered for the number of blocks in a track or track group, since we can equally well proceed to any track on the drum (except, of course, it is easier to stay on the last track used).

Technical Memorandum 63-2423-8 by L. E. Gallaher contains a description of queueing applied to a drum system.

Features:

It is believed that the concept of queueing a work list for a sequential memory allows such memories to be used in higher throughput applications than would be possible without such queueing.

Comparison:

Although there are many techniques for improving the data flow rate into a sequential memory, it is believed that the method proposed here is the only way of increasing the data flow rate both into and out of a sequential access memory.

Use:

The primary use of this method will be to increase the throughput of sequential memories used for file purposes. It is best suited for storage and retrieval of independent blocks of data such as would occur in a "store and forward" communication system.

Urgency:

The use of the above method is planned for the ESS-DAC Message Store in order to meet the system throughput objectives. The use of this method is imperative to the system.

Original signed by
R. W. Ketchledge

HO-2423-LEG-VFP

R. W. KETCHLEDGE

Att.
Technical Memorandum MM-63-2423-8

206

MM.

No. 1 ESS - Data Administration Center - Message Store Queueing - Case 39215-2 and 200513

FEB 11 1964

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Original signed by
R. W. Ketchledge

HO-2423-LSG-VFP

R. W. KETCHLEDGE

Att.
Technical Memorandum MM-63-2423-8

ELECTRONIC SWITCHING LABORATORY

COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE— No. 1 ESS - Ways of Increasing Throughput of DAC Message Store - Part II

MM 64 - 2423 - 2

CASE CHARGED— 39215-25

FILING CASES— 39215-2

DATE— March 3, 1964

AUTHOR— L. E. Gallaher

FILING SUBJECTS—
Memories
Sequential Memories

ABSTRACT

This memorandum describes a method of queueing that is adaptable to the Burroughs Disc File. The organization of information storage on the discs is presented. This organization, along with queueing, provides sufficient throughput to meet the DAC system requirements.

E-1932-C (5-63)

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E-1932-D (11-61)

BELL TELEPHONE LABORATORIES
INCORPORATED

SUBJECT: No. 1 ESS - Ways of Increasing Throughput of DAC Message Store - Part II - Case 39215-2

DATE: March 3, 1964

FROM: L. E. Gallaher
MM-64-2423-2

MEMORANDUM FOR FILE

Introduction

This memorandum is the second of the two memoranda* discussing techniques for increasing the throughput of the Message Store for the Data Switching System. The first memorandum covered the basic idea of queueing and its application to the Bryant Drums. This memorandum discusses a queueing system for the Burroughs Disc File.

Disc File Background

The Burroughs Disc File has a data head for each data track making it adaptable to the queueing concepts as discussed in Part One.

A total of 1200 active data heads and tracks is provided in each memory unit. These heads are multiple flying units with 13 heads mounted in each data head block. Each memory unit contains four discs as shown in Figure 1. The discs are mounted 2 on each side of the bearing housing with the drive motor mounted below the main frame and connected by belts to the disc shaft. The speed of rotation is about 1500 rpm. The discs on each side are closed in a dust-tight cover to protect the discs and heads from possible damage and minimize maintenance.

Each disc face is divided into three data zones plus one clock zone. Each data zone contains 50 tracks while 6 tracks are provided in the clock zone. Actually 52 tracks are located in each data zone but two are allotted by the manufacturer as spares and wiring is provided to only 50 heads per zone. The zone locations are shown in Figure 2. Two clock channels per disc side are assigned to each data zone, providing a bit clock and a word clock per zone. As used by Burroughs each disc face is treated as a separate memory with a new address search required whenever data is to be transferred from a different zone or disc face.

*Part I - MM-64-2423-8 - December 30, 1963

The discs are capable of recording better than 1000 bits per inch with NRZ (non-return to zero) recording, with less than a 50% reduction in readout amplitude from that obtainable at low bit densities.

Proposed Storage Organization for DAC

The proposed storage arrangement is designed to optimize the throughput of data with queueing and at the same time, to hold the bit densities as close as practical to those normally used by the Burroughs Corporation. Basically, each disc face is divided into 16 identical sectors, one of which is shown in Figure 3. The zone divisions are identical to the zone division of Figure 2. The angular subdivision of the sector is of more importance. The larger sector is the data section while the smaller sector is the control section. Thus on each disc there are 16 data sections and 16 control sections. Furthermore, the storage arrangement is such that all disc faces are essentially at the same relative position (relative to their data heads) at any given time. That is, when a particular data head on either side of disc one is entering the data section of sector 3, all heads of all discs are entering the data section of sector 3.

The time required to cross a data section is 2290 µsecs, a control sector 210 µsecs (assuming exactly 1500 rpm for the disc rotational speed).

This organization is designed so that during the control section, any data head can be selected, and during the data section, one block (32 words of 24 bits) of data can be transferred to or from the message store. The data block transferred could be any block of data in that sector of the entire disc file.

Within a sector, the data is organized as shown in Figure 3. In Zone 1, three blocks per track are provided; Zone 2 has four blocks per track; Zone 3 has five blocks per track. Moreover, the words of each block on each track are interleaved. Thus for Zone 1, Track 0, the sequence of words within a data section is:

Word 0 of Block 0
Word 0 of Block 1
Word 0 of Block 2
Word 1 of Block 0
etc.

Each word is written as a series string of 24 bits on a track. Two guard bits are used to separate each word from its adjacent word. Since NRZ recording is to be used, the first guard bit time is used to turn the read or write current off or on. The second guard bit is always recorded as a one so that the first flux change on readout will be known to be a zero. Thus each Zone 1 data track contains 2,494 bits per data sector or a bit frequency of 1.09 mc. Bit frequencies for Zones 2 and 3 are 1.45 mc and 1.82 mc respectively.

The word transfer rate, because of the word interleave, is the same regardless of the zone. At the disc nominal rotational speed of 1500 rpm, the word transfer rate is one word every 71.5 µsec or one word for thirteen 5.5 µsec system cycles. Since the speed tolerance is about ±5%, the word transfer rate may run as high as one word for 12 system cycles or as low as one for 14 system cycles.

This storage arrangement provides for the storage of 73,728 blocks of data, or about 56.7 million bits of data. In terms of usable system information storage, this amounts to nearly 3000 messages of 250 words assuming a waste factor of 32% and a packing of 3 characters per memory word.

Queueing Applied to the Disc File (Proposal Three)

The queueing system best adapted to the disc file is an extension of the system Proposals One and Two discussed in Part I. The queueing system suggested is a queue of 16 instructions corresponding to the 16 sectors around the drum. The instruction for a given sector could be for any block within that sector and would not be limited to odd or even as in Proposal Two for the drum. Two queueing lists would still be provided in the Buffer Store so that one can be prepared by the system while the other is being executed by the Buffer Control - Message Store complex.

With this queueing system the system would probably prepare only one queue list at a time which should occur once each revolution of the disc file (40 msec). Thus the system would have to prepare a queue more frequently than with the other proposals, but need only perform a 1 out of 16 sorting rather than 1 out of 28 or 32. This is important in that the probability for filling a queue of 16 is higher than for filling a queue of 32 from a given work list.

A comparison of the throughput for the Burroughs Disc File (Proposal Three) with Proposal Two discussed in Part I is shown as Figure 4. For values of "c" (number of entries in the push-down list considered for filling the queues) less than 40, the throughput is better for Proposal Three. In terms of block transfers per revolution (BTR) Proposal Three throughput is always as high or higher than Proposal Two but the decreased rotational speed of the disc file relative to the drums results in lower throughput per unit time for large values of "c".

The values for BTR for Proposal Three are derived from the following equation:

$$BTR = B\left[1 - \frac{(B-1)^c}{B^c}\right]$$

where B is the number of sectors around the disc.

This equation is taken from equation (5), Part I, except that the factor of one half is removed from the equation since any of the sectors can be utilized in each revolution in Proposal Three whereas only one half could be used per revolution in Proposal Two. Thus, for B = 16, the above equation reduces to:

$$BTR = 16 - \left(\frac{15}{16}\right)^c$$

Summary

Proposal Three as used with the Burroughs disc file will provide a Message Store capable of storing more than 70,000 blocks of data with a throughput of 330 blocks per sec. This throughput corresponds to a data transfer rate at the DAC terminals of 90 thousand bits per sec. for two characters per memory word and 120 thousand bits per sec. for three characters per memory word. Since the three character packing seems most likely the disc system will be able to provide the 100 thousand bits per sec. throughput specified for the DAC system.

L E Gallaher

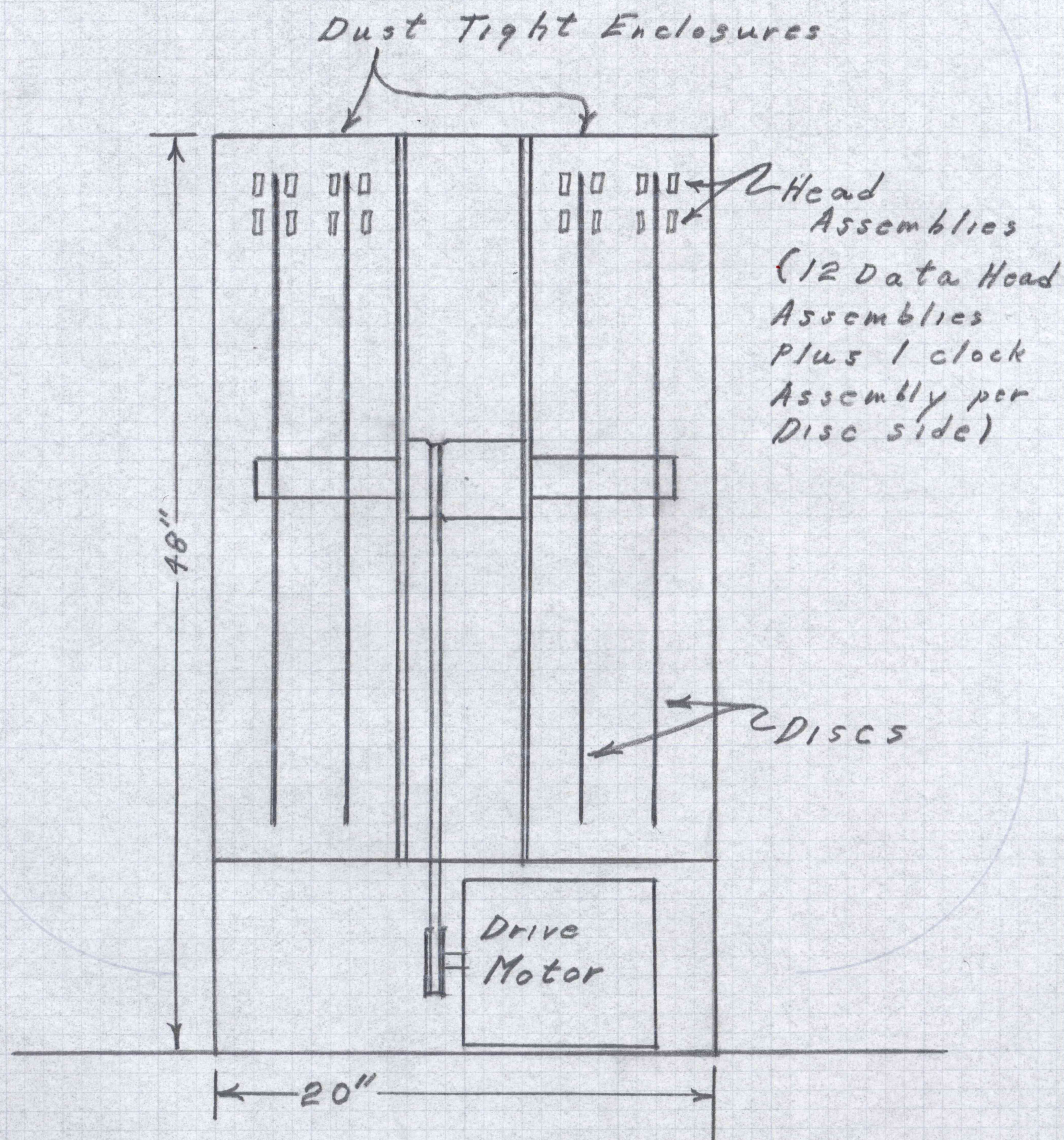
HO-2423-LEG-VFP

L. E. GALLAHER

Att.
Figures 1 - 4

$7\frac{11}{16}$

$10\frac{5}{8}$



Not to Scale

ISSUE	ENGR / DRAWN	TITLE	BELL TELEPHONE LABORATORIES INCORPORATED
Fig 1	ENGR: LEG DRAWN: 3 15 64	Disc Memory Unit End View	SHEET: NO. OF SHEETS PER SET:

ISSUE

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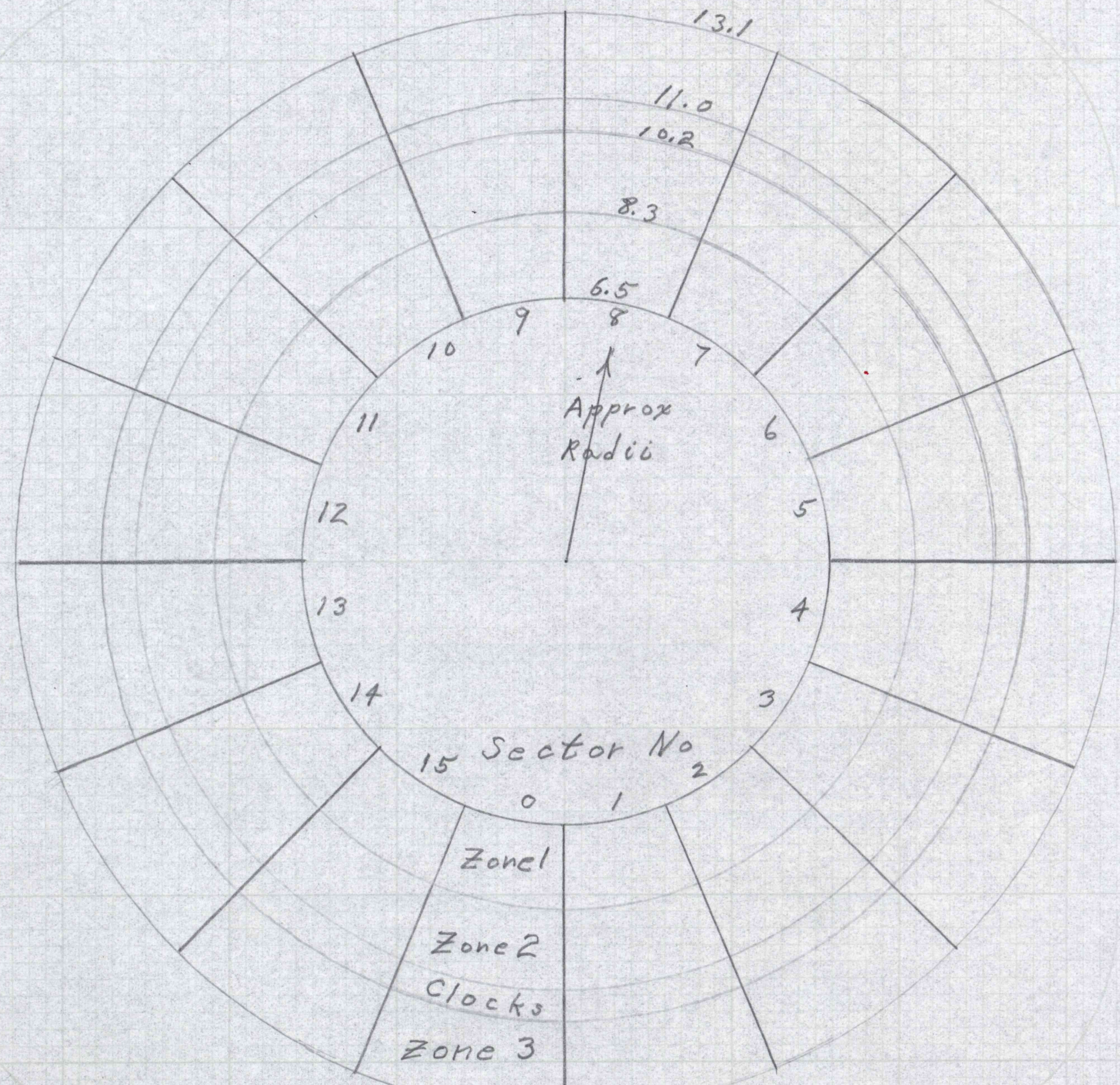
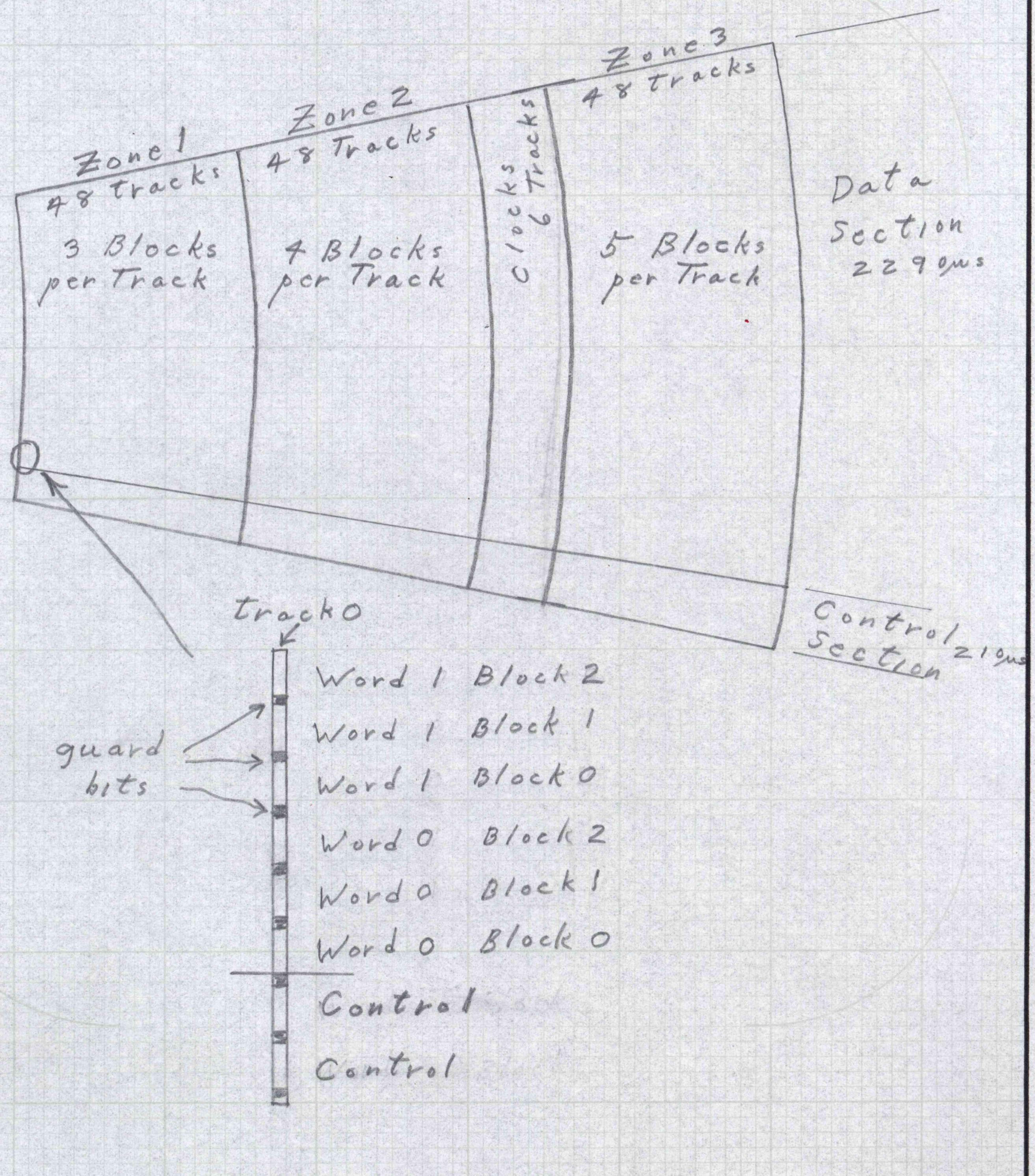
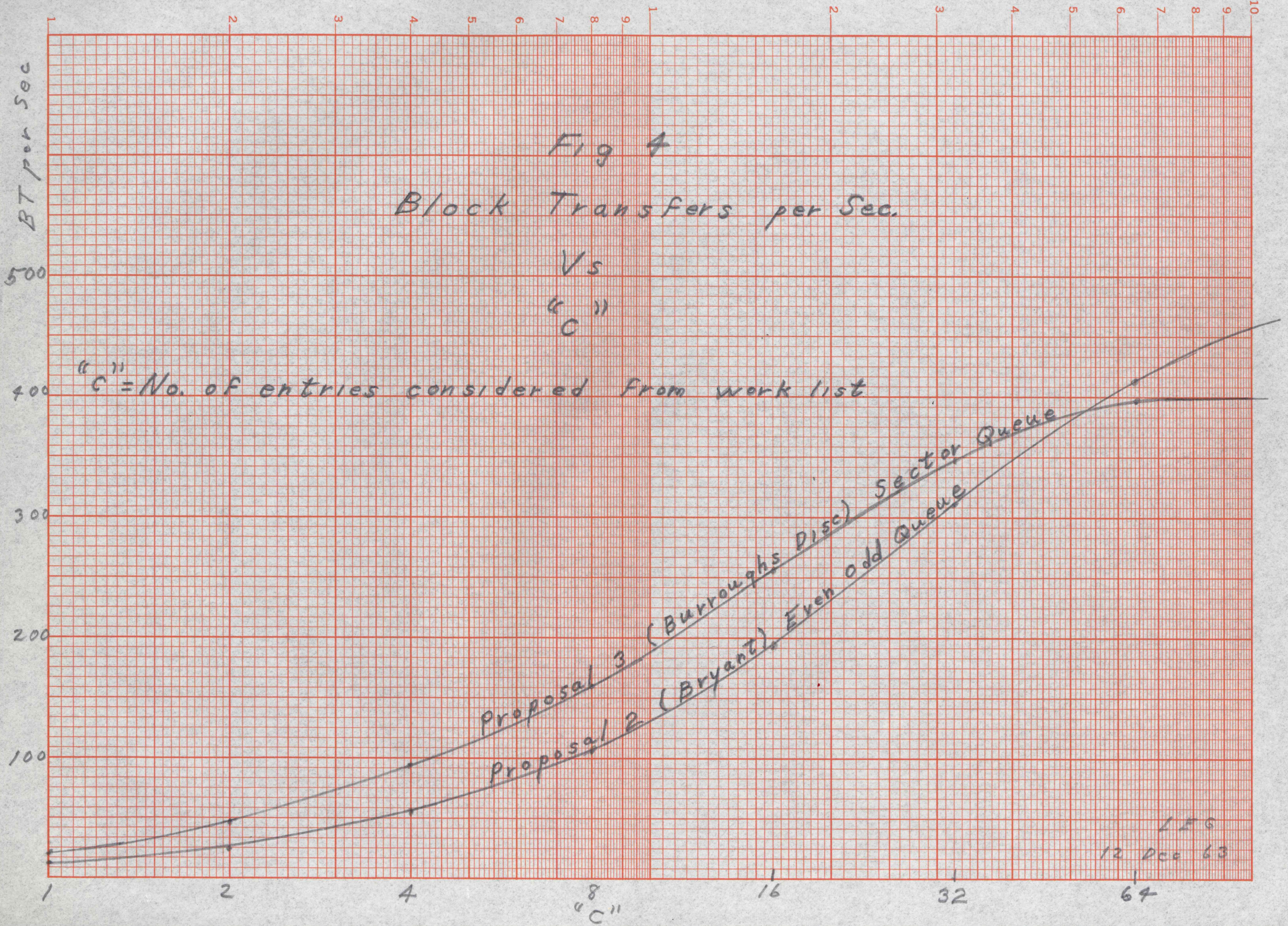


ISSUE	ENGR	TITLE	BELL TELEPHONE LABORATORIES INCORPORATED
Fig 2	LEG	Zone and Sector Divisions on Disc Face	SHEET
	DRAWN 3/17/64		NO. OF SHEETS PER SET



ISSUE	ENGR	TITLE	BELL TELEPHONE LABORATORIES INCORPORATED
Fig 3	LEG	Disc Sector Utilization	SHEET
	DRAWN		NO. OF SHEETS PER SET


K+E SEMI-LOGARITHMIC 359-62
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 84 DIVISIONS
Fig 4
Block Transfers per Sec.
Vs
"C"
"C" = No. of entries considered from work list
Proposal 3 (Burroughs Disc) Sector Queue
Proposal 2 (Bryant) Even odd Queue
BT per sec
500
400
300
200
100
1
2
4
8
16
32
64
"C"
LEG
12 Dec 63

No. 1 ESS - Ways of Increasing Throughput of DAC Message Store - Part II - Case 39215-25

March 3, 1964

L. E. Gallaher

MM-64-2423-

ABSTRACT

This memorandum describes a method of queueing that is adaptable to the Burroughs Disc File. The organization of information storage on the discs is presented. This organization, along with queueing, provides sufficient throughput to meet the DAC system requirements.

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March 3, 1964

L. E. Gallaher

MM-64-2423-

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Summary

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DAC - Release of Technical Memoranda - Case 39215-1

JUN - 9 1964

MR. D. B. ERWIN
Assistant Superintendent
Development Engineering
WECo - Columbus, Ohio

In connection with Mr. K. L. Kloberdanz's function to perform liaison efforts between the Bell Telephone Laboratories and the Columbus Works regarding the DAC system, we are releasing to him the following technical memoranda:

MM 63-2423-8	No. 1 ESS Ways of Increasing Throughput of DAC Message Store Part 1 by L. E. Gallaher
MM 64-2423-2	No. 1 ESS Ways of Increasing Throughput of DAC Message Store Part 2 by L. E. Gallaher

In releasing this information it is understood that you will take the necessary precautions to prevent any compromise of this material with people outside the company, since knowledge of the circuits, equipment and technical content may impair our patent rights.

ORIGINAL SIGNED BY
C. P. MARCHETTO

C. P. MARCHETTO
Head
Electronic Switching Projects
Equipment Department

HO-2444-KLK-PAS

APPROVED:

Original signed by
R. W. Ketchledge

R. W. Ketchledge

Copy to
Messrs. L. E. Gallaher - HO
J. P. Hoffmann - HO

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INCORPORATED

E-7111 (12-54)

DAC - Release of Technical Memoranda - Case 39215-1

JUN - 9 1964

MR. D. B. ERWIN
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WECo - Columbus, Ohio

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ORIGINAL SIGNED BY
C. P. MARCHETTO

C. P. MARCHETTO
Head
Electronic Switching Projects
Equipment Department

HO-2444-KLK-PAS

APPROVED:

Original signed by
R. W. Ketchledge

R. W. Ketchledge

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J. P. Hoffmann - HO

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INCORPORATED

E-7111 (12-54)

L Gallaher,
Dec 12 '63

Block Transfer Requirements for #1 ESS DAC Message Store

Assumptions

Number of 100 w/m lines = 700
Multiple address factor = 2
Words per block = 32
% Waste - text and message stored together = 18%
% Waste - Text and message stored separately = 27%

Load factor	.8		.9		1.0	
Message and text stored together (T) Separately (S)	T	S	T	S	T	S
Blocks per sec	142	160	159	179	177	200
Blocks per rev. at 1800 rpm Bryant	4.74	5.33	5.30	5.96	5.90	6.67
Blocks per rev. at 1500 rpm Burroughs	5.68	6.40	6.36	7.16	7.09	8.00

For Work List of 32 orders
Most Probable number of block transfers obtainable

Bryant		Burrough	
even-odd Queue structure	10.20	Sector Queue structure	13.98

Ratio of Block transfers obtainable to Max Blocks transfers required

Bryant $\frac{10.2}{6.67} = 1.53$ Burroughs $\frac{13.98}{8.00} = 1.75$

10.

10-0			.1
9-1	32.7 +	34.5	1.3
8-2	32.5	40.5	6.6
7-3	34.1	40.8	18.1
6-4	36.6	39.8	32.1
5-5	38.4	38.4	19.6
			~~82.6~~ 77.8 $\times \frac{500}{512}$ 76.2

11.

10-1	32.8	34.5	.8
9-2	32.7	40.5	4.0
8-3	32.5	40.8	12.1
7-4	34.6	39.8	~~23.2~~ 24.6
6-5	36.6	38.4	~~32.8~~ 34.6 $\times$ ~~1.024~~ 976 74.4
			~~72.7~~ 76.1

12.

11-1	33.0	34.5	.4
10-2	32.8	40.5	2.4
9-3	32.7	40.8	8.1
8-4	32.5	39.8	17.9
7-5	34.6	38.4	29.9
6-6	36.6	36.6	16.9
			75.6 x .976 73.8

13.

12-1	33.1	34.5	x	.2
11-2	33.0	40.5	78/4	1.4
10-3	32.8	40.8	286/4	5.3
9-4	32.7	39.8	715/4	13.0
8-5	32.5	38.4	1287/4	22.8
7-6	34.6	36.6	1716/4	30.5
				73.2 x .976 71.5

14.

13-1	33.2	34.5		.1
12-2	33.1	40.5	91/8	.8
11-3	33.0	40.8	364/8	3.4
10-4	32.8	39.8	1001/8	9.1
9-5	32.7	38.4	2/8	17.8
8-6	32.5	36.6	3/8	25.9
7-7	34.6	34.6	1716/8	14.8
				71.9 x .976 = 70.2

15	13-2	33.2	40.5	x 105	= .5
	12-3	33.1	40.8	455	2.1
	11-4	33.0	39.8	1365	6.2
	10-5	32.8	38.4	~~3003~~	13.3
	9-6	32.7	36.6	5005	21.6
	8-7	32.5	34.6	6435	27.0
				16387	70.7 x .976 = 69.1

16.	14-2	33.3	40.5	120	.3
	13-3	33.2	40.8	560	1.3
	12-4	33.1	39.8	1820	4.1
	11-5	33.0	38.4	4320	9.8
	10-6	32.8	36.4	8000	17.3
	9-7	32.7	34.6	11420	24.0
	8-8	32.5	32.5	6430	13.1
				32710	69.9 x .976 = 68.2

17.	15-2				.2
	14-3	33.3	40.8	680	.8
	13-4	33.2	39.8	2380	2.7
	12-5	33.1	38.4	6190	6.9
	11-6	33.0	36.4	12380	13.4
	10-7	32.8	34.6	19450	20.5
	9-8	32.7	32.5	24300	24.8
				65380	69.3 x .976 = 67.6

0			38	
1.		19.0 + 34.5 =	53.5	
2.		34.5 + 34.5 x $\frac{1}{2}$	34.5	~~64.5~~ 64.5
		40.5 + 19 x $\frac{1}{2}$	~~29.5~~ 30	
3.	30	40.8 + 19 x $\frac{1}{4}$	15.0	71.2
	21	37.5 + 40.5 x $\frac{3}{4}$	56.2	
4.	40	37.8 + 19 x $\frac{1}{8}$	7.4	
	31	40.8 + 37.5 x $\frac{1}{2}$	37.6	75.4
	22	40.8 + 40.5 x $\frac{3}{8}$	30.4	
			75.4	
5.	50	38.3 + 19 x $\frac{1}{16}$	3.6	
	41	39.8 + 37.5 x $\frac{5}{16}$	23.1	
	32	40.8 + 40.5 x $\frac{10}{16}$	51	77.7
			77.7	
6.	6-0	36.6 + 19 x $\frac{1}{32}$	1.88	
	5-1	38.3 + 37.5 x $\frac{6}{32}$	13.6	
	4-2	39.8 + 40.5 x $\frac{15}{32}$	37.5	
	3-3	40.8 + 40.8 x $\frac{10}{32}$	25.5	78.4
			78.4	
7.	7-0	~~3.46~~	.9	
	6-1	36.6 + 37.5 $\frac{7}{64}$	7.8	
	5-2	38.4 + 40.5 $\frac{21}{64}$	25.9	
	4.3	39.8 + 40.8 $\frac{35}{64}$	44.0	78.6
			78.6	
8.	8-0		.4	
	7-1	34.6 + 34.5 $\frac{8}{128}$	4.3	
	6-2	36.6 + 40.5 $\frac{28}{128}$	16.8	
	5-3	38.4 + 40.8 $\frac{56}{128}$	34.5	77.8
	4-4	39.8 + 39.8 $\frac{35}{128}$	21.8	
			77.8	
9.	9-0		.2	
	8-1	32.5 + 37.5 x $\frac{9}{256}$	2.4	
	7-2	34.6 + 40.5 x $\frac{36}{256}$	10.6	
	6-3	36.6 + 40.8 $\frac{84}{256}$	25.4	
	5-4	38.4 + 39.8 $\frac{126}{256}$	38.5	77.1
			77.1	

75.2

1.9
3.7
$\frac{51.3}{?} = 1.77$
2
3.57

$$\frac{10 \times \overset{3}{\cancel{9}} \times \overset{4}{\cancel{8}}}{\cancel{6}} = 120 \times \frac{7}{4} \quad 210$$

$10 \times 9 \times$

$\frac{10}{1} \times \frac{9}{2} \times \frac{8}{3} \times \frac{7}{4} \times \frac{6}{5}$ 1260

10 45 120 210 252

4! = ~~24~~

$11 \times \frac{10}{2} \times \frac{9}{3} \times \frac{8}{4} \times \frac{7}{5}$

55 165 330 ~~434~~ 462

$12 \times \frac{11}{2} \times \frac{10}{3} \times \frac{9}{4} \times \frac{8}{5} \times \frac{7}{6} \times \frac{6}{5}$

66 220 495 792 $\frac{924}{2}$ 462

4096

$13 \times \frac{12}{2} \times \frac{11}{3} \times \frac{10}{4} \times \frac{9}{5} \times \frac{8}{6} \times$

78 286 715 ~~1277~~ 1287 ~~1536~~ 1716

1836
1377
715
286
78
13
1

$14 \times \frac{13}{2} \times \frac{12}{3} \times \frac{11}{4} \times \frac{10}{5} \times \frac{9}{6} \times \frac{8}{7}$

91 364 1001 2002 3003 $\frac{3432}{2}$

1716

3432

8192

$15 \times \frac{14}{2} \times \frac{13}{3} \times \frac{12}{4} \times \frac{11}{5} \times \frac{10}{6} \times \frac{9}{7}$

105 455 1365 3003 5005 6435

1716
3003
2002
1001
364
91
14
1
8192

2730
2730
30030

$16 \times \frac{15}{2} \times \frac{14}{3} \times \frac{13}{4} \times \frac{12}{5} \times \frac{11}{6} \times \frac{10}{7} \times \frac{9}{8}$

120 560 1820 4370 × 8000

11420 $\frac{12860}{2}$

$17 \times \frac{16}{2} \times \frac{15}{3} \times \frac{14}{4} \times \frac{13}{5} \times \frac{12}{6} \times \frac{11}{7} \times \frac{10}{8}$

136 680 2380 6190 12,380 19,450 24,300

16/2,2!

1		1 0 (100)					
2.		2-0 (50)	1-1 (50)				
3.		3-0 (1/4)	2 1 (3/4)				
4		4-0 (1/8)	3-1 (~~2 1~~ 1/2)	2-2 (3/8)			
5	32	5-0 (1/16)	4-1 (5/16)	3-2 (10/16)			
6	64	6-0 (1/32)	5-1 (6/32)	4-2 (15/32)	3 3 (10/32)		
7	128	7-0 (1/64)	6-1 (7/64)	5-2 (21/64)	4-3 (35/64)		
8	256	8-0 (1/128)	7-1 (8/128)	6-2 (28/128)	5-3 (56/128)	4 4 (35/128)	
9	512	9-0 (1/256)	8-1 (9/256)	7-2 (36/256)	6-3 (84/256)	5-4 (126/256)	
10	1024	10-0 (1/500)	9-1 (10/500)	8-2 (45/500)	7-3 (120/500)	6-4 (210/500)	5-5 (~~210/500~~ 126/500)
11		~~10-1 (11/1000)~~	9-2 (55/1000)	8-3 (165)	7-4 (330)	6-5 (462)	
12		~~10-2 (66/2)~~	9-3 (220/2)	8-4 (495/2)	7-5 (792/2)	6-6 (462)	
13		11-2 (78/4)	10-3 (286/4)	9-4 (715/4)	8-5 (1287/4)	7-6 (1716/4)	
14		12-2 (91)	11-3 (364)	10-4 (1001)	9-5 (2002)	8-6 (3003)	7-7 (1716)
15		13-2	12-3	11-4	10-5	9-6	8-7
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							

Table II

$\frac{10!}{10} = 2$

10!
9
19

10!

180
1440
10080
60480
~~302400~~ 1512005

~~4!~~
5! = 120
6! = 720
7! = 5040
8! = 40320
9! = 362880
10! = 3,628,800

1! = 1
2! = 2
3! = 6
4! = 24
5! = 120

2048
4096
4100
8200
16400
32800
65600
131,200
262,000
524,
1048
2100
4,200

7-3
33.33
1.19

5-5
30.000
7.3
×2
74.6

6-4
30.5

66

11/12 333

0							19.0		19
1	1/2	16.67	+1.19	17.86		16.66	34.52		34.5
2	3/4	25.00	+1.19	26.19	~~28~~	14.28	40.47		40.5
3	5/6	27.7	1	28.89	~~13.90~~	11.90	40.79		40.8
4	7/8	29.1	1	30.3	~~11.52~~	9.52	39.82		39.8
5	9/10	30.0	1	31.2	~~8.14~~	7.14	38.34		38.3
6	11/12	30.6	1	31.8	+ ~~5.76~~	4.76	36.56		36.6
7	13/14	31	1	32.2	+ ~~2.38~~	2.38	34.58		34.6
8	15/16	31.3	1	32.5	+ 0	0	32.5		32.5
9	17/18	31.5			8/9 1			33.9	32.7
10	19/20	31.6						34.0	32.8
11	21/22	31.8						34.2	33.0
12	23/24	31.9						34.3	33.1
13	25/26	32.0						34.4	33.2
14	27/28	32.1						34.5	33.3

~~Straight Time~~ ~~Rise~~ ~~3.8~~

Check p 1-2   750 at 100%

does DSEP suggest 700 terminal of 80% load

p 1-6

hold entire message until transmission complete. - 9.2.5

32,

~~8~~ 9.6 1 3 5 9

28

28 number

8 ~~B-tinker~~ boxes

32 [illegible]

$\frac{8}{28}$ n $x^{10} \approx 3$

1 2 3

$\frac{1}{2}$ $\frac{3}{4}$ $\frac{5}{6}$

1 28 number

5 8 boxes

19 5 out of 28

1/7

any card $\frac{1}{28}$ 1 1 1 1 [illegible]

1.1 9 [illegible] / B

$\frac{1}{28}$

1. 9. $\frac{1}{2}$ [illegible] 16.67

9. No 9 16.65

No 9 19

$10 \times \frac{26^{10}}{28^{10}}$

1.44716
1.41497
.03219

.3219

2.051

$\frac{120}{12} \approx 10$

$\frac{5!}{2!\,3!}$

case 1 case 2

9, 3/4 25 16.67
14.3 16.67
16.67
19 16.67
16.65
83.35 58.3 67.33 [illegible] 62.5

6 5/2

$\frac{1}{16}$ $\frac{5}{16}$ 2/3

3, 1/2 3/4
27.8 25
11.9 14.3
19 16.67
16.65
58.7 72.62

4. $\frac{1}{8}$ $\frac{7}{8}$ 29.1 9.5 19 57.6

1/2 3/3
27.8 25
11.9 14.3
16.67 25
16.67 17.3
73.03 786

40 04 13 13 13 13 31 31 31 31 22 22 22 22 22 22

5 31 7.3 19 57.3

29.1 9.5 16.7 16.7 720

25 14 27.8 11.9 787

50 200

3 chan/w 3/3/64

	Words H 16.7 ~~25~~	Word Text 66.7 ~~100~~	%	16.7 ~~25~~	66.7 ~~100~~	Combined ~~Combined~~
4	8.25	2.2	50	58.25	52.2	53.4
8	18.3	5.3	25	43.3	30.3	32.9
16	32.0	10.5	12.5	44.5	23.0	27.3
24	41.6	15.1	8.333	49.93	23.43	28.7
32	48.8	19.3	6.25	55.05	25.55	31.5
48	58.9	26.5	4.167	63.07	30.67	37.2
64	65.9	32.5	3.125	69.03	35.62	42.3

4 $\frac{16.7}{2} = 8.33$ $\frac{.75}{8.33+.75}$ 9.08 $\frac{.75}{33.3+.75}$ 34.05

8.8
8.25
17.05 × 2 = 3.41

8 $\frac{6}{7}$ $\frac{.625}{2.78+.625}$ 3.405 $\frac{.625}{11.1+.625}$ 11.725

21.2
18.3
39.5 × 2 = 7.9

16 14 $\frac{.56}{1.19+.56}$ 1.75 $\frac{.56}{4.76+.56}$ 5.32

42.0
32.
74 × 2 14.8

24 22 $\frac{.54}{.758+.54}$ 1.298 $\frac{.54}{3.04+.54}$ 3.58

60.4
41.6
102.0 20.4

32 30 $\frac{.53}{.554+.53}$ 1.084 $\frac{.53}{2.22+.53}$ 2.75

77.2
48.8
126.0 × 2 25.2

48 46 $\frac{.52}{.361+.52}$ .881 $\frac{.52}{1.45+.52}$ 1.97

106.0
58.9
164.9 × 2 32.98
33.0

64 62 $\frac{.515}{.268+.515}$ .783 $\frac{.515}{1.07+.515}$ 1.585

130.0
65.9
195.9 39.18
39.2

	25	100	125	2 Bit %	25	100	125
4	5.65	1.5	1.2	50	55.65	51.5	51.2
8	13.05	3.6	2.9	25	38.05	28.6	27.9
16	24.3	7.3	5.95	12.5	36.8	19.8	18.45
24	32.1	10.6	8.67	8.333	40.4	18.93	17.0
32	39.0	13.7	11.3	6.25	45.25	19.95	17.55
48	48.8	19.4	16.1	4.167	52.97	23.57	20.27
64	56.1	24.3	20.4	3.125	59.23	27.43	23.53

$\frac{25}{2}$ $\frac{.75}{12.5+.75}$ $\frac{.75}{50.75}$ $\frac{.75}{62.5+.75}$ $\frac{1.5}{64}$

$\frac{25}{6} = \frac{.625}{4.16+.625}$ $\frac{.625}{16.67+.625}$ $\frac{.625}{20.83+.625}$ 1.35 $\frac{1.35}{21.18}$

$\frac{25}{14} = \frac{.56}{1.75+.56}$ $\frac{.56}{7.15+.56}$ $\frac{.56}{8.9+.56}$ $\frac{1.12}{10.02}$ 1.12

$\frac{25}{22} = \frac{.54}{1.14+.54}$ $\frac{.54}{4.55+.54}$ $\frac{.54}{5.69+.54}$ $\frac{1.08}{6.77}$ $\frac{.54}{6.23}$

$\frac{25}{30} = \frac{.53}{.833+.53}$ $\frac{.53}{3.333+.53}$ $\frac{.53}{4.167+.53}$ $\frac{1.06}{5.227}$

$\frac{25}{46} = \frac{.52}{.545+.52}$ $\frac{.52}{2.17+.52}$ $\frac{.52}{2.715+.52}$ $\frac{1.04}{3.75}$

$\frac{25}{62}$ $\frac{.515}{.404+.515}$ $\frac{.515}{1.61+.515}$ $\frac{.515}{2.014+.515}$ $\frac{1.03}{2.04}$

4	52.33
8	30.49
16	23.2
24	23.22
32	25.1
48	29.45
64	33.79

4	2.35	52.35
8	1.35	31.35
16	11.2	23.7
24	16.0	24.33
32	20.2	26.45
48	27.8	31.97
64	34.0	37.13

to increase throughput

put half words or alternate words on one track and other part on reverse ~~side of~~ counterpart track of ~~opposite~~ disc in other half of memory.

Use blocks of 64 words.

2 char per word.

Wastage R

$330 \times .629 \times 768 \times .75 \cancel{\times 2 \times \frac{2}{3}}$

$\simeq 159.3$ Kc $\quad c = 32$

$= 193.0$ Kc $\quad c = \emptyset$

3 char per word.

$.75 \times 2$

$330 \times 57.7 \times 768 \times 1.5$

$= 220$ Kc $\quad c = 32$

$= 266$ Kc $\quad c = \emptyset$

to increase throughput. Mar 2 64

Present throughput.
No maintenance
330 B/s for c = 32
400 B/s c = ∞

System throughput
2 char/word.
wastage 6.7s 3/4 factor for MA factor = 2

330 B/sec × .73 × 768 × .75
= 138 Kc c = 32
= 167 Kc c = ∞

138 Kc × 2/3 = 92 Kc
167 Kc × 2/3 = 111 Kc
11.5 Kc char/sec
13.9 Kc char/sec

System throughput
3 char/word.
330 B/sec
330 / B sec / × .6 ~~55~~ × 768 × .75 ×
= ~~[illegible]~~ ~~[illegible]~~
= 129 Kc for c = 32
= 157 Kc for c = ∞

90
110

120
145

C BTR 12 Dec 63

	Bryant	Barrough.		
1	.5	1.0	15	25
2	.99	1.9	29.7	47.5 ~~76~~
4	1.96	3.65	59	91.2 ~~146~~
8	3.56	6.45	107	161 ~~8~~
16	6.37	10.31	191	258 ~~327~~
32	10.2	13.98	312	350 ~~327~~
64	13.9	15.74	417	395
128	15.72	15.996	475	400

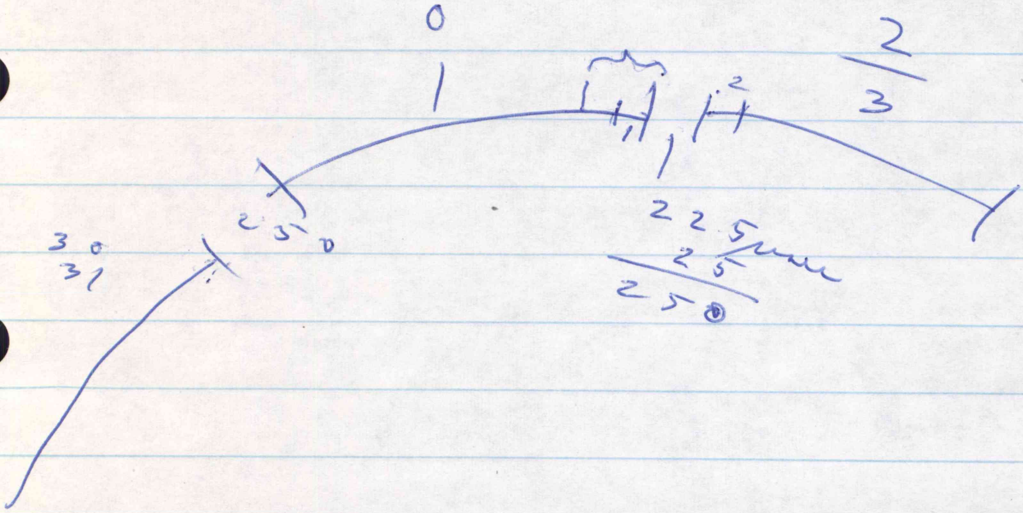
Plot as Fig 7

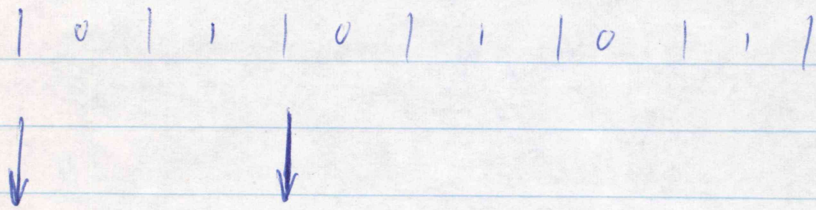
Table III

Number of Drum Revolutions Required to ~~transfer 2M order~~ empty the queues of M orders.

M	Revolutions	M	Revolutions
0	1.14	15	2.08
1	1.60	16	2.05
2	1.93	17	2.03
3	2.14	18*	2.0
4	2.26	19*	2.0
5	2.33	20*	2.0
6	2.35	21*	2.0
7	2.36	22*	2.0
8	2.33	23*	2.0
9	2.31	24*	2.0
10	2.29	25*	2.0
11	2.23	26*	2.0
12	2.20	27*	2.0
13	2.15	28*	2.0
14	2.10		

*Not calculated.

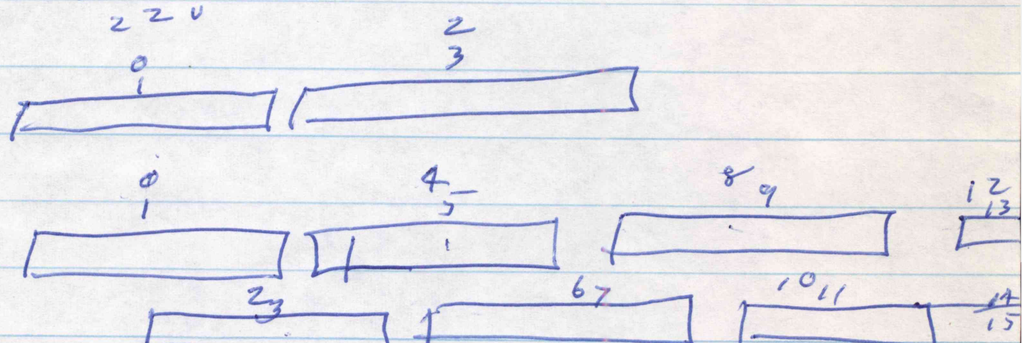


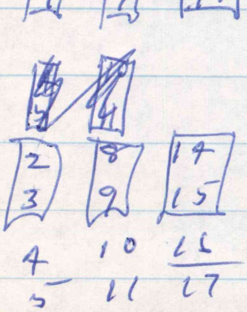


9 3 x 55 165

per Lord 1 55

220





P of n for any slot of Q for Q of 32 with 128 overflow Blocks

is $\frac{128!}{n!\,(128-n)!} \times \frac{31^{(128-n)}}{32^{128}}$

most likely number of 0's

is $32 \times \frac{31^{128}}{32^{128}}$

$= \frac{32^{128} - 128 \times 32^{127} + \frac{128 \times 127}{2} \times 32^{126}}{32^{127}} \times \frac{128 \times 127 \times 126}{3 \times 2} \times 32^{12}$

$= 32 - 128 + \frac{\cancel{64}^{2} \times 127}{\cancel{32}} - \frac{\cancel{128}^{4} \times 127 \times \cancel{126}^{63}}{\cancel{32} \times \cancel{32}_{8} \times 3 \times \cancel{2}} + \frac{128 \times 127 \times 126 \times 125}{32 \times 32 \times 32 \times 4 \times 3 \times 2}$

$= 32 - 128 + 254 - 333 +$

$\times \frac{128}{32} \times \frac{127}{32 \times 2} \times \frac{126}{32 \times 3} \times \frac{125}{32 \times 4} \times \frac{124}{32 \times 5} \times \frac{123}{32 \times 6} \times \frac{122}{32 \times 7} \times \frac{121}{32 \times 8} \times \frac{120}{32 \times 9}$

$= 32 - 128 + 254 - 333 + 325 - 252 + 162 - 88 + 41.5 - 17.4$

$\times \frac{119}{32 \times 10} \times \frac{118}{32 \times 11} \times \frac{117}{32 \times 12} \times \frac{116}{32 \times 13}$

$+ 6.5 - 2.17 + .66 - .184$

	32	128	
	254	333	333.37
325.55	325	252	252.30
161.62	162	88	88.02
41.60	41.5	17.4	17.33
6.44	6.5	2.17	2.15
.65	0.66	.18	.18
	821.66	820.75	
	820.75		821.35
	821.86		
	821.35		
	.51		

should get 31 out of 32

P of n for Q of 32 with 128 cards in deck.

$$\text{is } 128 \times \frac{32!}{n!\,(32-n)!} \times \frac{127^{32-n}}{128^{32}}$$

~~P of 0~~

Most Likely # of misses $= 128 \times \dfrac{127^{32}}{128^{32}}$

$$= 128 \times \frac{(128-1)^{32}}{128^{32}}$$

$$= \times \frac{128^{32} - 32 \times 128^{31} + \frac{32 \times 31}{2} \times 128^{30}}{128^{31}}$$

P of n for Q of 32 with 128 cards to select from

is $\cancel{32}\ \cancel{x}\ \dfrac{128!}{n!\,(32-n)!} \times$

Elnicom

Capacity 131,072 data word storage locations identified by binary addresses 0–131,071

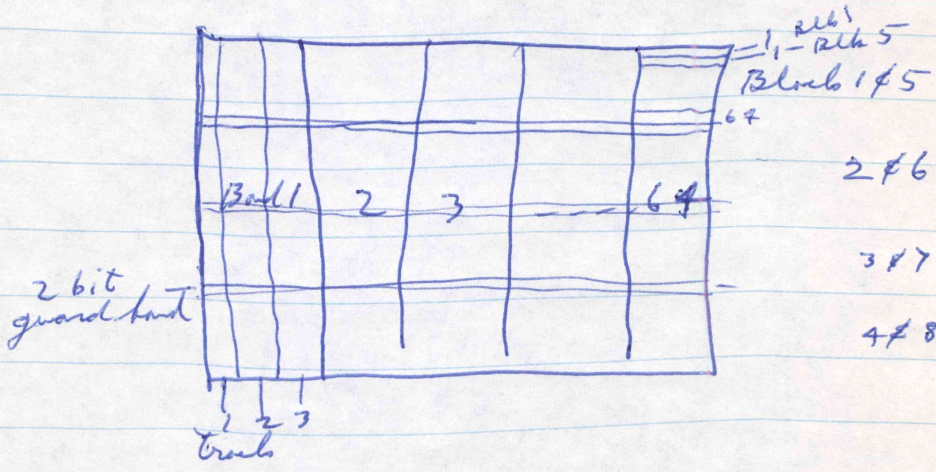
word is 24 bits (0 to 23)

basic drum stores 32,768 words, and 1 to 4 drums may be used.

Data Organization

data words 64 ~~blocks~~ bands of 512 words each.
Each data word band has 3 parallel tracks of 4104 bits / track. Data word bands are further divided in 8 blocks each storing 64–24 bit words, with interleave.

4096



512 x24
1024 12
4096 x 3

24 bit word is 8 bits in 3 tracks.

Access 4.2 msec average Max
Word transfer time from time initial address located on Drum is 27.8 μsec/w to 32.8 μsec/w
Block transfer time Transfer of 64 or 256 data word groups

64 Words Max 10.5 msec Min 1.8 ms Ave 6.55 Max Ave 7.35
6% Slip −5% freq 6% S +5% freq 0% s 0% freq 6% slip −5% freq

$\cancel{\frac{24}{33}}$

$\cancel{\frac{128}{72}}$ $\cancel{\frac{127}{144}}$ $\cancel{\frac{126}{216}}$ $\cancel{\frac{125}{288}}$ $\cancel{\frac{124}{360}}$ $\cancel{\frac{123}{432}}$ $\cancel{\frac{122}{504}}$

72 − 128 + 112.88 − 65.84 + 28.57 − 9.84 + 2.80 − .67

$\times \frac{121}{576}$ $\times \frac{120}{648}$ $\times \frac{119}{720}$

+.14

7200
1208
4 | 59.92

3

$\cancel{\frac{128}{64}}$

$\cancel{72}$

$\cancel{\frac{64}{72}}$ $\cancel{\frac{63}{144}}$ $\cancel{\frac{62}{216}}$ $\cancel{\frac{61}{288}}$ $\frac{60}{360}$ $\frac{59}{432}$

72 − 64 + 28 − 8.03 + 1.20 − .28 + .03

7200
2942
42.58

10.65
14.19

20 Oct 63

Holding time

Average message time = $41\frac{2}{3}$ sec

Message not ~~sent~~ erased out. 'till completely delivery

Message to tape cost ~~=~~ negligible holding time

For .8 loading,

M = message time 41 sec

total hold $\doteq \cancel{1 + 3\sqrt{2} + 1}$ = $1 + 3\sqrt{2}$

(the three terms of the struck-out sum are labelled: rec, hold + send)

$= \cancel{6.2}$ $= 1 + 3 \times 1.4$

$= \cancel{6.2 \times \frac{2}{3} \quad \frac{12.4}{3}}$ $= 5.2$

$= \cancel{4.8 \times \ldots}$ $\quad 5.2 \times \frac{2}{3} \approx 3.5$ min

$\cancel{4.8 \times \frac{41\frac{2}{3}}{60} \approx 3.5}$

For .9 loading.

total hold $= 1 + 5.5\sqrt{2} + \cancel{2}$

$= 1 + 7.7$

$= 8.7$

$8.7 \times \frac{2}{3} \approx 6$ min

4.5   1.4   55   7   7

For .95 loading.

$= 1 + 10.5\sqrt{2}$

$= 1 + 14.7$

$= 15.7 \times \frac{2}{3} \quad \frac{31.4}{3} \approx 10.5$ min.

10.5 × 1.4 = 420 + 105

2 Oct 63

Blockfree

100 w/m

600 c/m   10 c/sec   4 $\frac{1}{2}$

300 MSW/M/Entry   80 bits/sec + 30 bits/sec

5 MSW/S/Entry   Length $12\frac{1}{2}\%$

chain 6%

2800 MSW

~~3~~ M/S/

line ≈ 12 Blocks/min

$\frac{27}{32}$

$3\frac{1}{2}$ 18'

$\frac{6}{23}$

1.0 chr/sec

$$\begin{array}{r} 156 \\ 24\overline{)3750} \\ 24 \\ \hline 135 \\ 120 \\ \hline 150 \end{array}$$

768

9000 bit

19000/min

64 — 125 w

$2\frac{1}{2}$

32,000

156 Blocks/sec

25

~~3~~

~~28~~

100

$1\frac{1}{2}$ $\frac{1}{2}$

33

~~3~~

~~100~~

36

700

1400/sec

60

8400

64

~~60~~

384

6400

$38\overline{)3750}$

2' 3×1.4   ~~4~~.2 × $\frac{2}{3}$

900 MSW/sec

$\frac{1}{5}$

1200

30

~~200~~ $\frac{250}{6}$ characters.

$41\frac{2}{3}$ sec/message

$1\frac{1}{2}$ 400/sec

$1\frac{1}{2}$ min at 40 Blocks/sec

90

8

3600 Blocks.

32

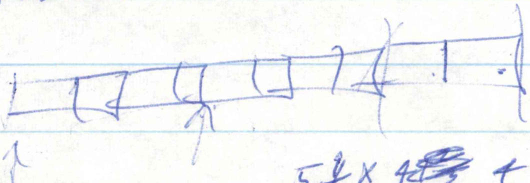
78

108

115,800

24

2700,000



$5\frac{1}{2}$ × ~~40~~ 40

225 × 1.4

225

9

2250

67

1280

16

1440

24

476

288

3356

48

325

365

2×10^6/min of Holding.

Bryant

Design 2 32 Block

Pair interleave

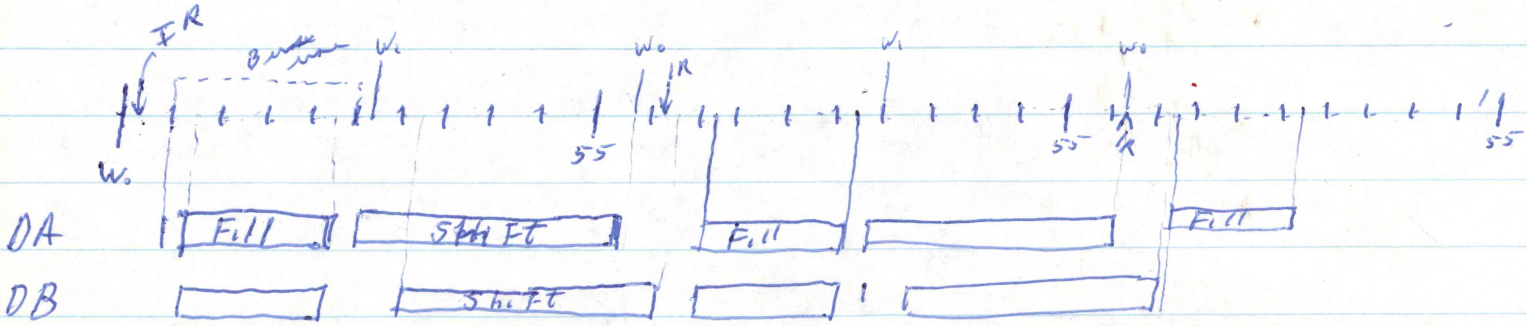
25 quess min quad / Block,

assume 2 quad bits / word.

and 1 in 10 bus utilization

and bus above within 4 cycles,

52 bits in 55 usec



Various Designs Possibly

	1	2	3	4
total Blocks Q	28	32	36 ~~72~~	36 ~~72~~
Interlace (word)	No	Yes	Yes	Yes
alternate block access	~~B~~ No	Yes	No	No
Slipped block	No	No	No	Yes
Q format	2×14	2×16	4× ~~18~~ 9	3× ~~24~~ 12
Revs to empty all Q	2	2	4	3
Max Blocks/rev	14	16	~~18~~ 9	~~12~~ ~~[illegible]~~ 12
~~Heat~~ Ave Block/rev PDL = 128	13.85	15.75	~~14.98~~ 7.5	~~17.97~~ 10.0
Bus use	1 in ~~10~~ 6	1 in 10	1 in 10	1 in 10
Max data rate drum	~~1.0577~~ $.73 \times 10^6$/rev	~~1.0577~~ $.945 \times 10^6$/s	~~1.0577~~ $.945 \times 10^6$/s	~~1.0577~~ $.945 \times 10^6$/s
Max data rate bus	$.73 \times 10^6$/s	$.473 \times 10^6$/s	$.473 \times 10^6$/s	$.473 \times 10^6$/s
# Registers	2	1	1	1
Ave Block/rev PDL = 64	12.7	13.9	10.65	14.19
			10%	10%

3.

I.T.

to increase throughput assume greater storage.

is C S storage for Blocks is doubled to 250%
500 lines require then 1250 Blocks of
32 words

~~1250~~ $\frac{1250 \times 32}{8192}$ 5 unduplicated
10 duplicated stores.

Bryant's case
128 positions
This should allow 4 reads per position
or 6 RW Block transfers in 140 + 50 msec
or 31.6 B/sec
= 512 x 31.6 or 16,150 bits/sec
handles 187 lines at 80% ~~LF~~
at extra 50,000 cost for cell stores.

~~Data file~~
Disc file 64 positions
should allow 8 reads per position.
same as last case or 30
310 lines.

Requirements

1 line generates 110 bits/sec

6.9 CSW/sec

.215 Block/sec

total Storage required ~~for~~ per 100 lines/24 hours at 2:1 read/write ratio

$$\frac{8,800}{3} \times 86,400$$

$$= 253 \times 10^6$$

assuming 26% wastage + 2% proud storage required 300×10^6

For 700 lines this would require

2.1×10^9 storage capability.

Dont know average load factor which should reduce this requirement.

tape at 3600 Bits/in and 2400 ft holds

~~867~~ 104×10^6 bits

≈ 20 tape reels at steady 80% LF

Notes on Disc File
for message store

Assumptions -
Bryant disc file 13 disc - 1200 rpm
(similar to Collins Project)

Read-write ratio 2-1

Average read access time 165 msec
140 for head positioning
25 for ~~\$x~~ disc rotation

32 - 24 bit words / Block.
(used by Collins plus 1 w for checks)

Resulting throughput ~~assuming 0~~ assuming 0
~~write time~~ write time
4,600 bits/sec
assuming 110 bits/sec per line and
80% occupancy this system
will handle 53 lines.
Collins states 200 lines which
must run lower occupancy (21%)

Line handling capability can be doubled
by doubling block length at the expense
of wasting storage ~~capabil~~ capacity due
to wastage per of blocks

total storage requirements for 24 message retrieval, assuming ~~24% occupancy of~~ ~~20~~ bit rate of ~~42,000 bits/sec~~ storage rate of 1533-bit/sec is 132×10^6 bit/day.

Capacity of ~~drum~~ disc file

240×10^6 bits - wastage.

32 w/B - Waste is 26%

Usable capacity 178×10^6 bits/day

checks OK.

For 64 word blocks.

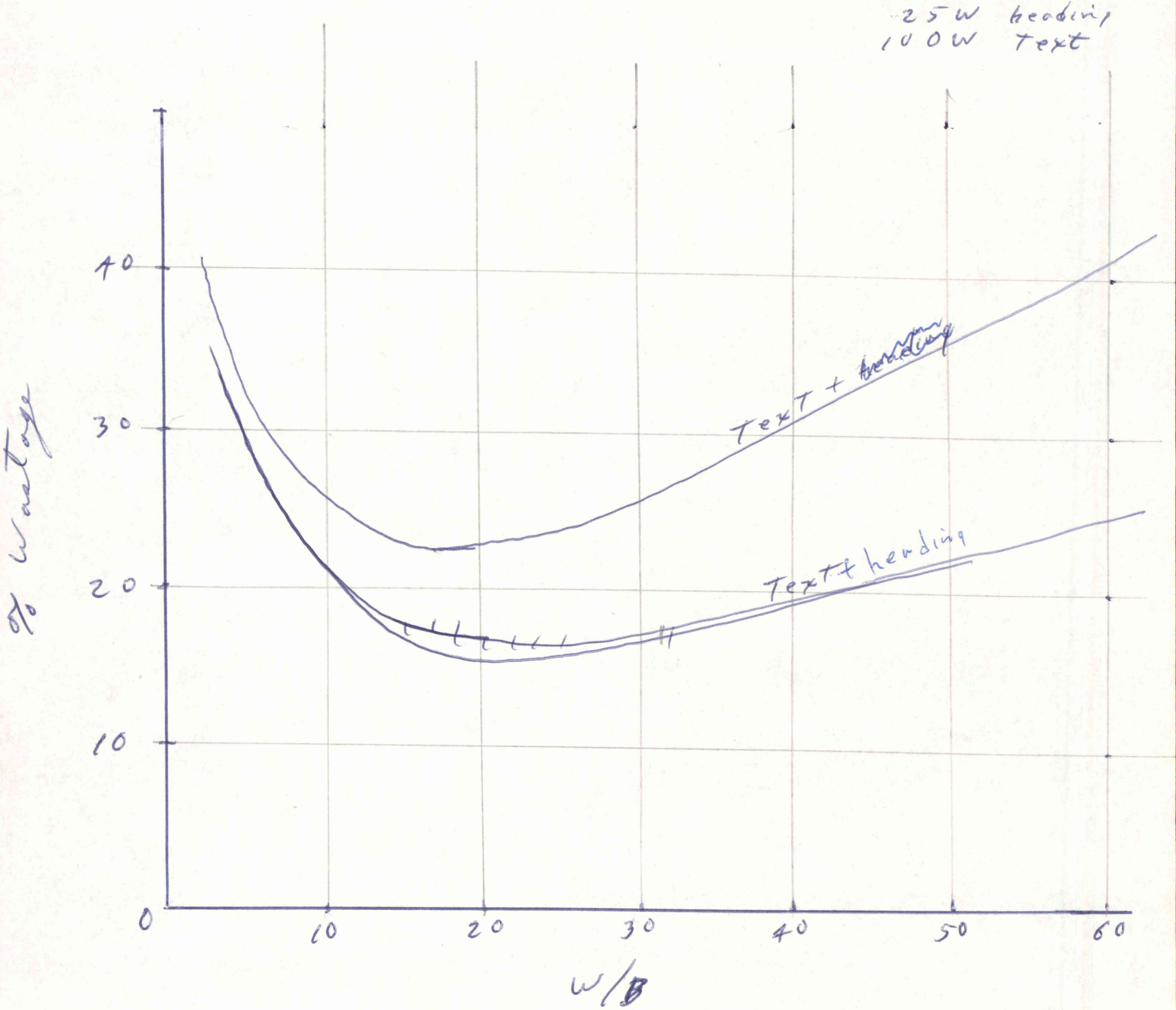
bit rate for storage is 3067 bits/sec

or 264×10^6 bits/day

Wastage is 44%

Usable storage 134×10^6

Ave Message length
125 W (2 characters)
25 W heading
100 W Text



$n! = \sqrt{2\pi}\, e^{-n}\, n^{n+\frac{1}{2}}$

for $n > 10$

for 128 tracks and q of 16.

Probability of 1 in track 1

$$\cancel{16 \cdot 15} \quad \frac{16!}{1!\,15!} \times \frac{127^{15}}{128^{16}} = \frac{(128-1)^{16}}{127 \times 128^{16}}$$

$$= \frac{16}{127} \times P(0) = .1112$$

14.25 tracks have 1

Probability of 0 in track 1

$$\frac{16!}{16!} \times \frac{127^{16}}{128^{16}} = \frac{(128-1)^{16}}{(128)^{16}}$$

$$= \cancel{\frac{127^{16}}{128^{16}}} = 128^{16} - 16 \times 128^{15} + \frac{16 \times 15}{2} \times 128^{14} - \frac{16 \times 15 \times 14}{3}$$

$$= 1 - \frac{16}{128} + \frac{120}{128^2} - \frac{\cancel{80} \times \cancel{14}}{\cancel{128} \times \cancel{128} \times 128}$$

$$= 1 - \frac{1}{8} + \frac{1}{128} - \frac{2}{3750}$$

$$= \begin{array}{r} 1.0078 \\ .1255 \\ \hline \end{array}$$

$= \cancel{.955}$

$.8823$

~~122 tracks have 0~~

113 tracks have 0

15 tracks have 1 or more

1 has 2 14 have 1

P of 2 on track 1

$$\frac{16!}{2!\,14!} \times \frac{127^{14}}{128^{16}} = \frac{16 \times 15}{2} \times \frac{(128-1)^{16}}{128^{16} \times 127^2}$$

$$= .8823 \times \frac{120}{127^2}$$

on any track $= .8823 \times \frac{120}{127} = .833$

2P

For 128 T $\quad Q = 8$

p not 0 on ~~[struck]~~ any trial.

$$= 128 \times \frac{127^8}{128^8} = \frac{(128-1)^8}{128^8}\,128$$

$$= 128\left(1 - \frac{8}{128} + \frac{28}{128^2} - \frac{56}{128^3}\right)$$

$$= 128 - 8 + .22 \qquad \frac{56}{128}$$

$$= 120.22$$

$p \geq 1$ any trial $= 7.78$ $\quad$ only $\frac{1}{4.5}$ p of 2 or more or 22%

for 64 T $\quad Q = 8$

$$\#T \text{ with } 0 = 64 \times \frac{63^8}{64^8} = 64 \times \frac{(64-1)^8}{64^8}$$

$$= 64\left(1 - \frac{8}{64} + \frac{28}{64^2} - \frac{56}{64^3}\right.$$

$$= 64 - 8 + .44 - .01$$

$$= 56.43$$

43% p of 2 or more

64T $\quad Q = 16$

$$\#T \text{ with } 0 = \overset{64}{\cancel{128}} \times \frac{(64-1)^{16}}{64^{16}}$$

$$= \overset{64}{\cancel{128}}\left(1 - \frac{16}{64} + \frac{\overset{8\ 120}{16 \times 15}}{2 \times 64^2} + \frac{\overset{8\ 5}{16 \times 15 \times 14}}{3 \times 2 \times 64^3}\right.$$

$$= \frac{128 - 32 + 3.75 - .273 + .015}{2}$$

3.75
.15
131.765
32.273
98.492
2

$= 49.246$ ∴ 14.75 trials have 1 or more

36
24
144

Disc file

512 tracks / disc 256/side
8 heads per disc 64 position
each disc 10^7 bits 225 ms average accessline
average access 225 two extra discs
~~the~~ Each disc side has 2 zones of 128 tracks
Data rate is 250 Kc inner and 500 Kc outer zone
12.5K bits/track 25K bits/track.

For 32 X 24 ~~word~~ block | $\begin{array}{r}128\\64\\\hline 268\end{array}$
16 blocks/track 32 B/T

Assume 16 disc with 16 ~~arms~~ head positioner,
all of which can function separately
on address command. (Not provided on old units)
Read time for ~~Q of 8 plus~~ 2 Q's of 8
= 225 + ~~4~~ X 25
= ~~325~~ msec for ~~8~~ 5 blocks.

~~20 B/sec read~~
~~30 B/sec total~~
~~at 32 W/B = 32 X 16 X 30 bits/sec~~
~~= 15000 bit/sec~~

15.4 B/sec read
7.8
23.2 B/sec total
bit rate = 512 X 23.2 = 11,900
at 80% loading will handle 135 lines

2 D

Part of 0 for 8 ~~tied~~ positives for 8 Q

$\frac{\cancel{8}^{2} \times 7 \times \cancel{6} \times \cancel{5}}{\cancel{4} \times \cancel{3} \times \cancel{2}}$

$= 8 \times \frac{7^8}{8^8} = 8 \times \frac{(8-1)^8}{8^8}$

$(8-1)^8 = 8^8 - 8 \times 8^7 + 28 \times 8^6 - 56\,8^5$

$= \cancel{8 \times 8}$

$= 8 - \cancel{8} + \frac{28}{8} - \frac{56}{8 \times 8} + \frac{70}{8 \times 8 \times 8} - \frac{56}{8^4}$

$\frac{8 \times 7 \times \cancel{6} \times \cancel{5 \times 4}}{\cancel{5 \times 4} \times \cancel{3 \times 2}}$

$= 3.5 - .875 + .137 - .0137$

$= 3.637$
$\quad .889$
$\quad 2.748$

5.252

Part of 0 for 8 positives for 16 Q

$= 8 \times \frac{7^{16}}{8^{16}}$

$= \frac{8}{8^{16}} \times \frac{(8-1)^{16}}{} = \frac{8^{16}}{8^{15}} - \frac{16 \cdot 8^{15}}{8^{15}} + \frac{120}{8} - \frac{\cancel{16} \times \cancel{15} \times \cancel{14}}{\cancel{3} \times \cancel{2} \times \cancel{8} \times \cancel{8}}$

OK

$= 8 - 16 + 15 - \frac{35}{4} + \frac{14}{4} - \frac{21}{20} + \frac{1}{4} \frac{\cancel{16} \cdot \cancel{15} \cdot 14 \cdot 13}{4 \times \cancel{3} \cdot \cancel{2} \cdot 8 \cdot \cancel{8} \cdot \cancel{8}}$

$= 7 - \quad - 5 -$

$\frac{\cancel{14}}{4} \times \frac{\cancel{12}}{5 \times \cancel{8}}$

$\frac{1}{6} \times \frac{(16-1)^8}{16^8}$

$\frac{21}{20} \times \frac{11}{6 \times 8}$

$\frac{16^8 - 8 \times 16^7 + 28 \cdot 16^6 - 56 \cdot 16^5 + 70 \cdot 16^4 - 56 \cdot 16^3}{16^7 \quad 16^7}$

$\frac{231}{960}$

$16 - 8 + \frac{28}{16} - \frac{56}{16 \times 16} + \frac{70}{16 \times 16 \times 16}$

$8 + 1.75 - .219 + .017$

9.5

3 D

Assume 3, Q's of 8

= 225 msec for 5 Block.

at 80% LF serves $\frac{325}{225} \times 135 = 195$ lines.

~~Assume 2, Q's of 16~~

Assume we are rather smart and use ordered Q's to give continuous positioner action.

225 msec for 8 Blocks.

~~at 80 LF~~ or 35.6 Blocks/sec read

~~= 8~~ = 53.4 B/sec total

= 512 × 53.4 = 27,300 B/sec

at 80 LF = 310 lines.

Storage required 24 hr = 9,100 B/sec

9,100 × 86,400

= 785 × 10^6

36
24
144
72

at 26% wastage

Usable ~~storage~~ storage

is 155 × 10^6 − 26% or 115 × 10^6

not nearly enough for even four hours.

Requirements for Message store
Read = Write time.

Per 100 lines at 80% LF
≈ 8,800 bits/sec
≈ 17.2 Block/sec per 100 lines.

For 700 line system,
120 Block/sec.
1 Block every 8.33 msec
at 1800 rpm
4 Blocks per revolution. 33 ms

at 1200 rpm
6 Blocks per revolution. 50 msec

Present Bryant Drum capability 2 - ~~[illegible]~~ Queues of 8
with 6 CS

768 Block Storage

$$\begin{array}{r} 256 \\ \times 12 \\ \hline 768 \end{array}$$

~~≈ 10 Blocks~~
at least ≈ 10 Blocks/rev or 1750 line capability.

assuming Write time is 0 and multiple message ratio of 2/1 as assumed in other studies,
Present drum can handle ~~[illegible]~~ 2625 line

Meeting at Pasadena
Jan 7 '67

1

per zone
1 track

Segment address (3 characters)

1

Wd Mark.   1   1   1   1   1

Address

1 track   straight clock.

basis timing   BITP

Index pulse   INXP

Word timing

S $ 1 2 4 8 A B n 1 2 4 8 A B S

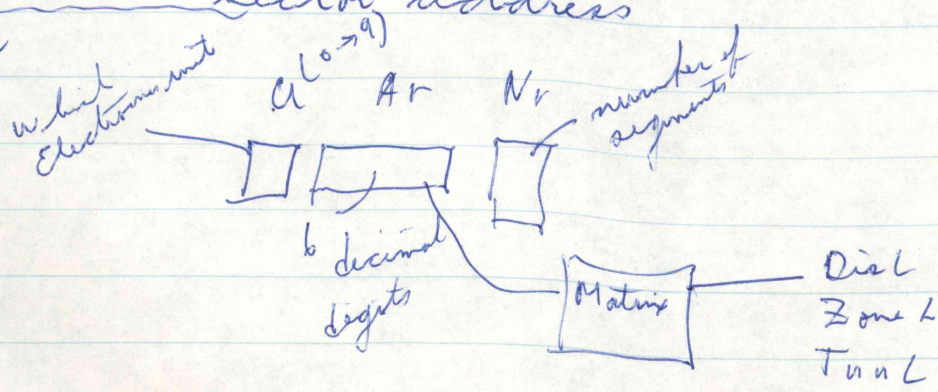
ICFF   Interlace

SCOL   Sector Coincidence level (must be on during word mark

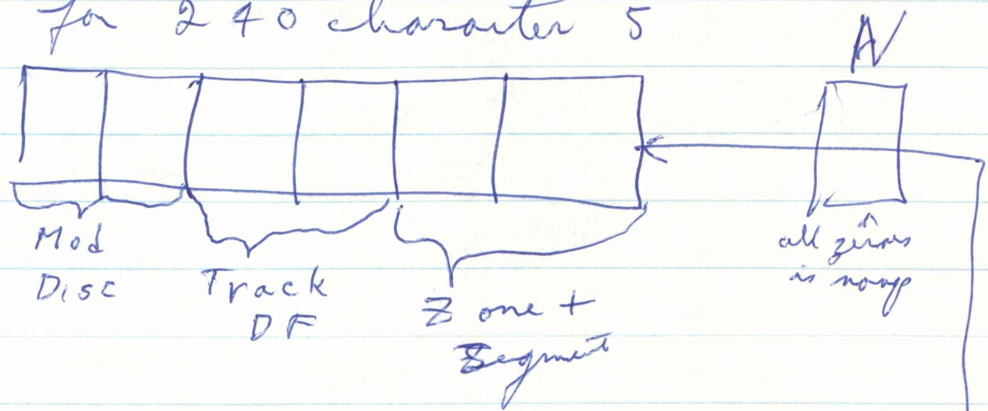
ACFF   Action FF

Use dead section of interleave to scan sector address

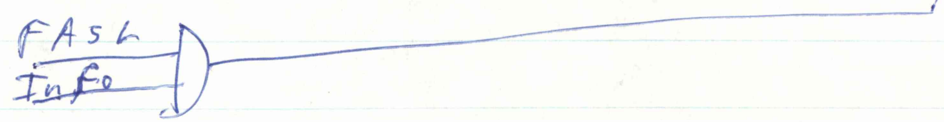
Register



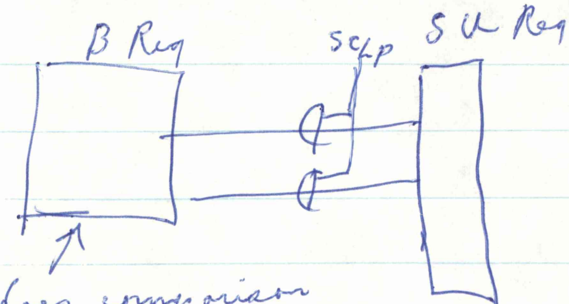
Ar for 240 characters



FASL — ~~FA~~ address select line

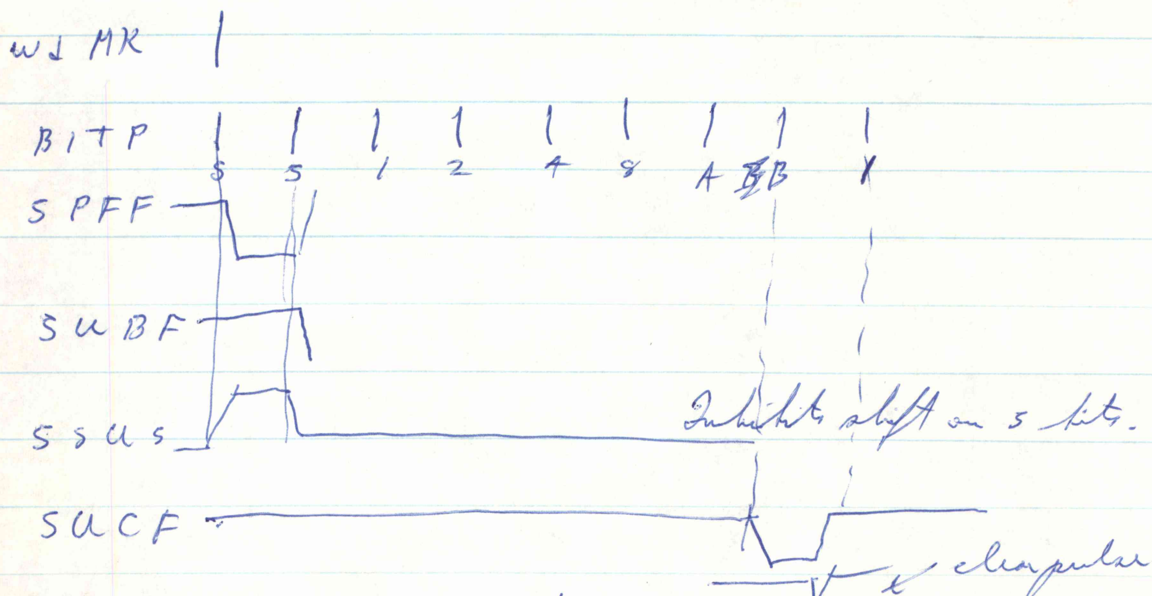


CS1L
CS2L } wired field in 475 indicators

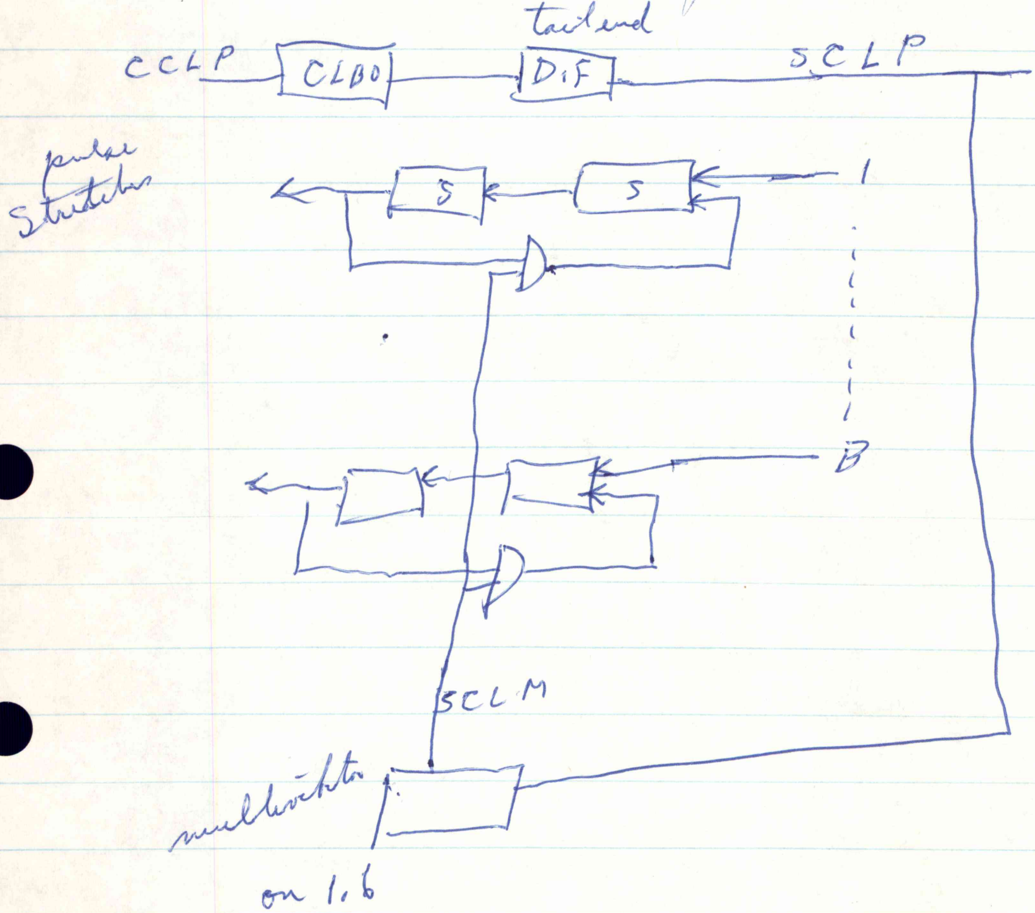


Does comparison of ~~of~~ segment address with 2 digits of Ar Reg.

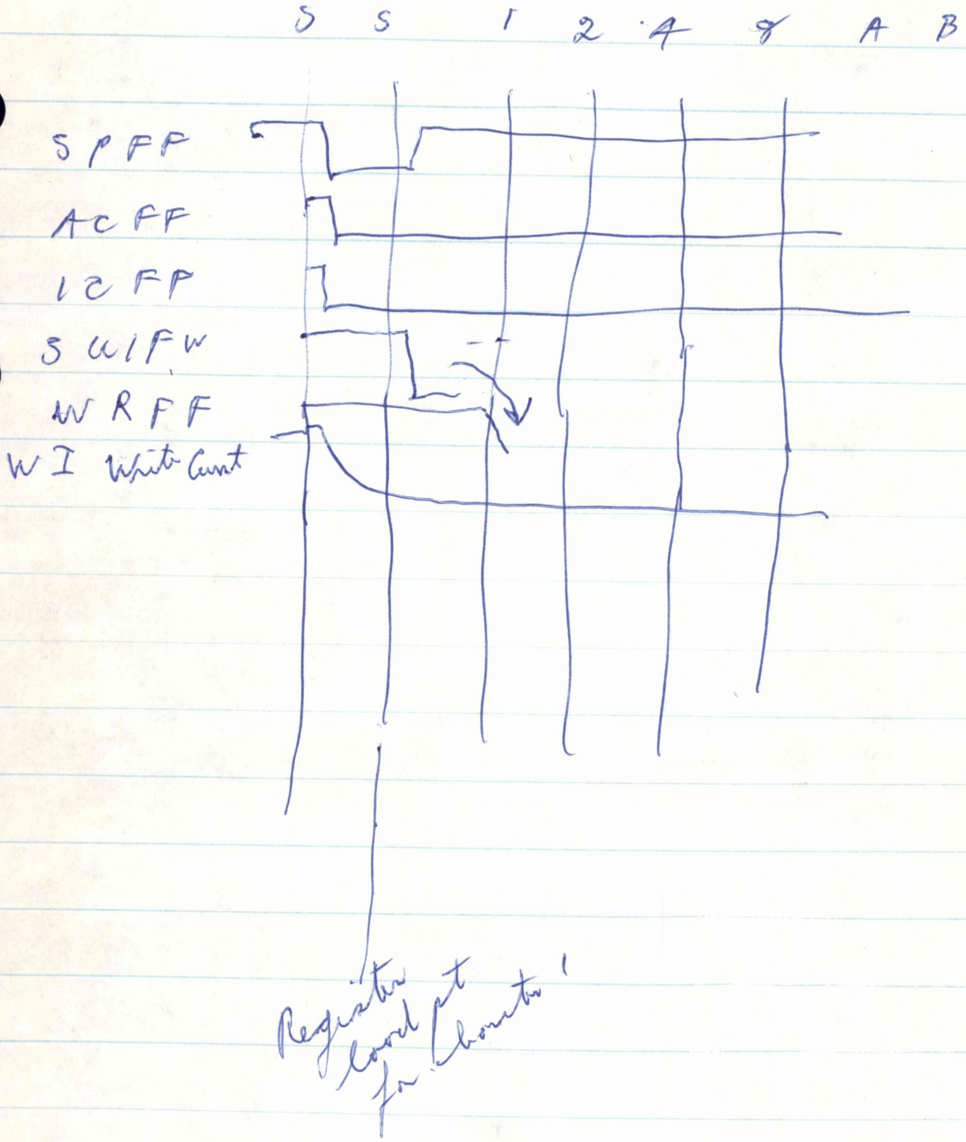
On SCLP we read SU, clear SU and insert 1 in SU BE~~...~~



C is placed in A and rest of SU register cleared meanwhile B bit of SU can still receive data.



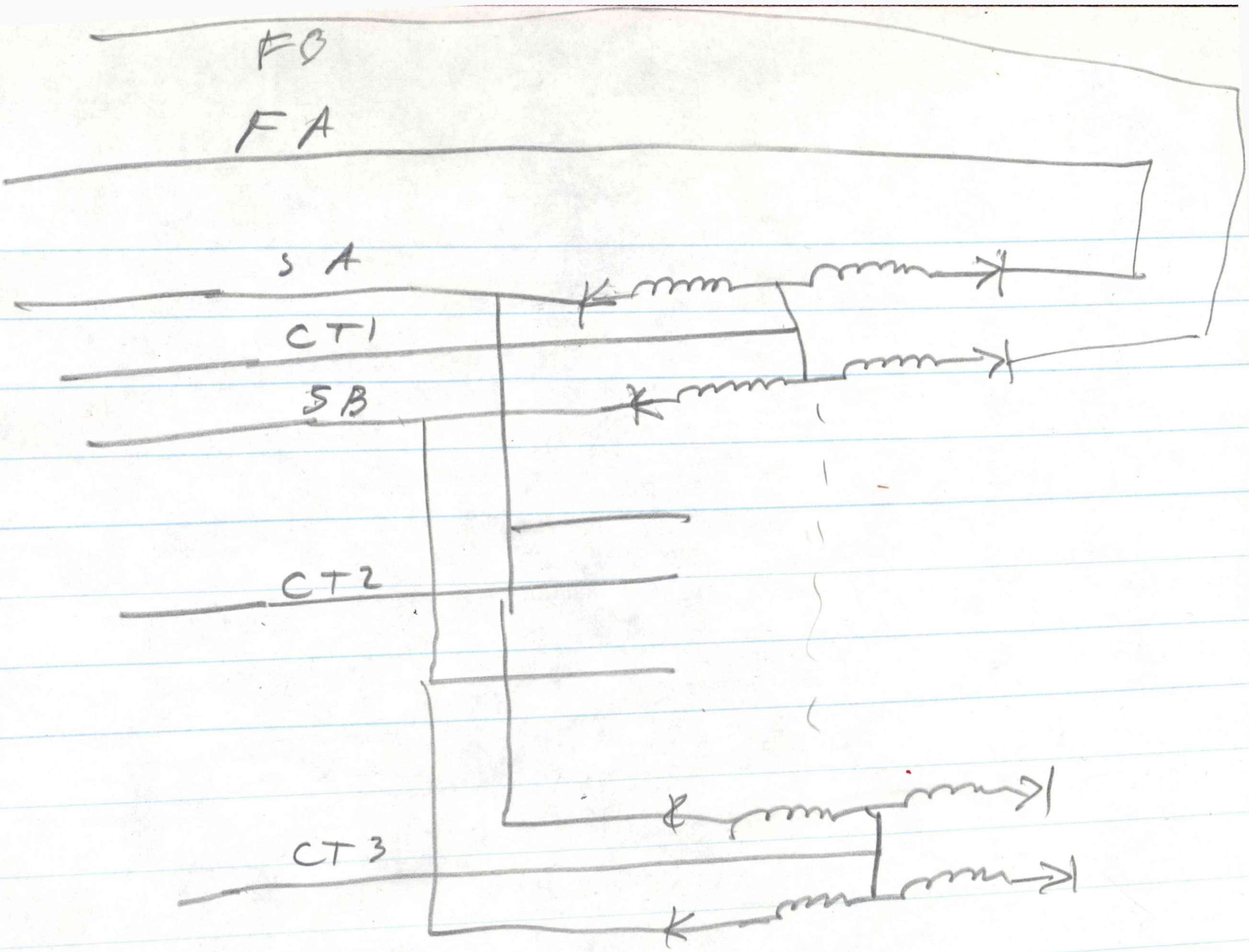
Write mode

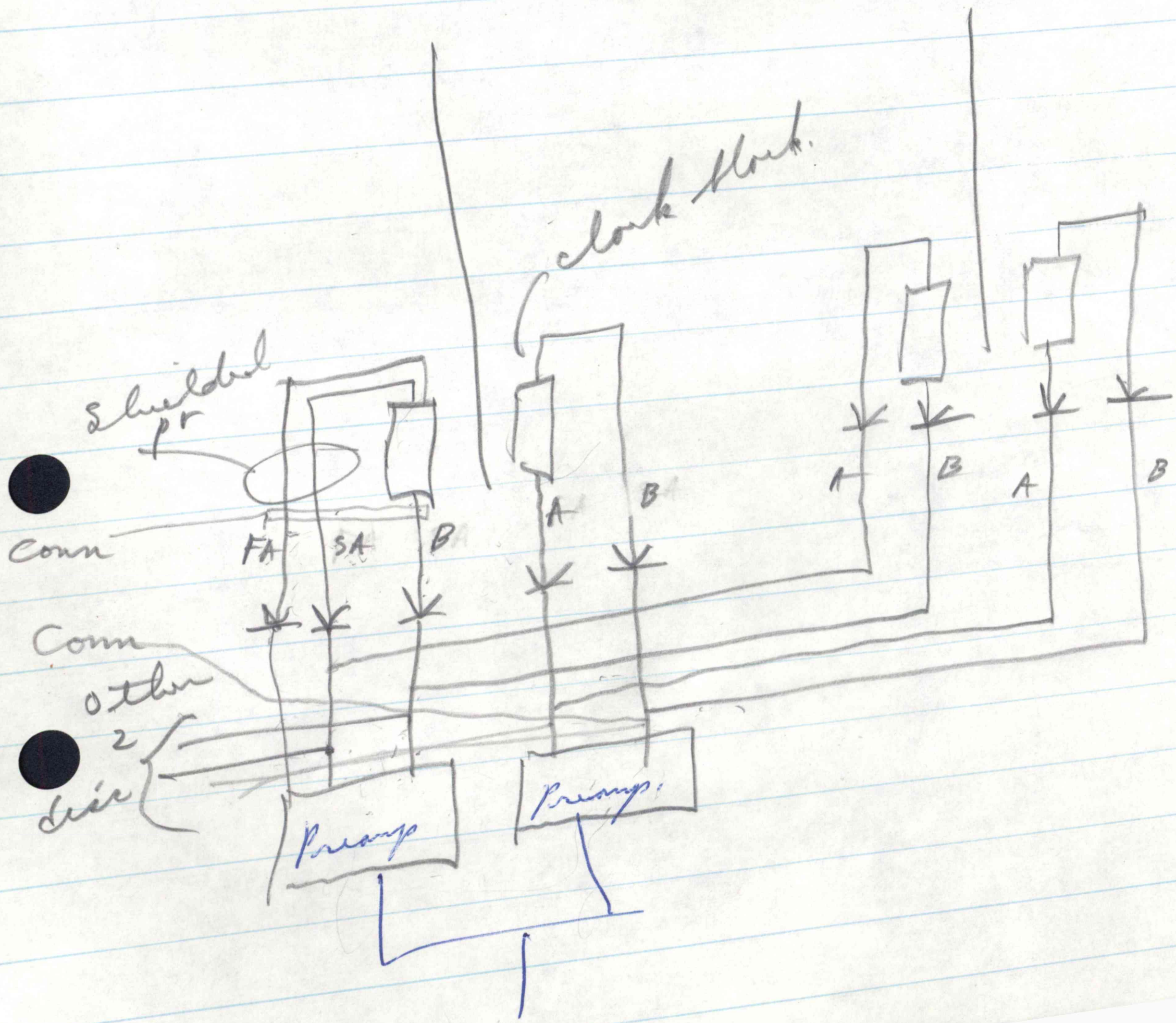

S S 1 2 4 8 A B
SPFF
ACFF
ICFF
SWIFW
WRFF
WI Write Count
Register load pt for character

1 8 Jan 64

Basic Mechanics - no change expected
Head wiring - " " "
head - may change
circuitry - may change

Concerned about long time high temperature


FB
FA
S A
CT1
SB
CT2
CT3


clock block
shielded pr
Conn
FA
SA
B
A
B
A
B
A
B
Conn
other
2
disc
Preamp
Preamp

Head Characteristics (Clock and Lotus)

30 μh total

8 per side

1 Ω per side.

8 mc resonance load alone.

Type 15

Microsemiconductor MC 1665

Diode Specs.

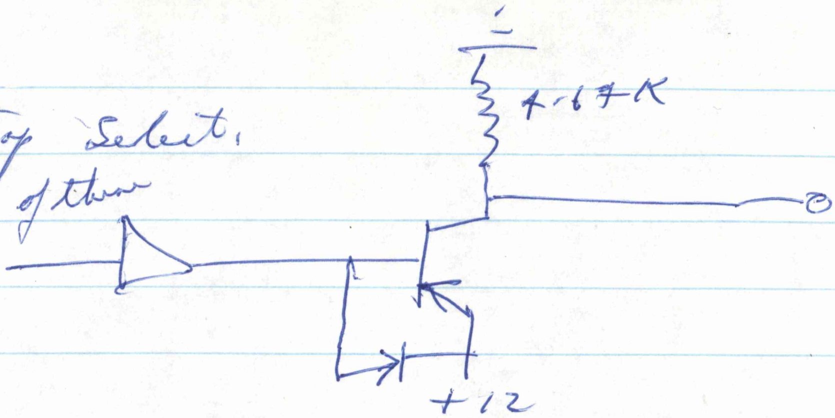
2 3500 31 #

3 13.7 pf/ft.

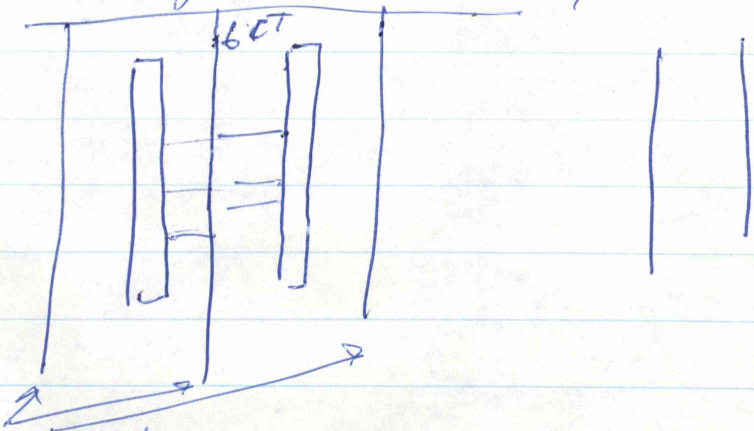
900 cu f 50

600 ohm/ft.

Center tap select,
100 of them

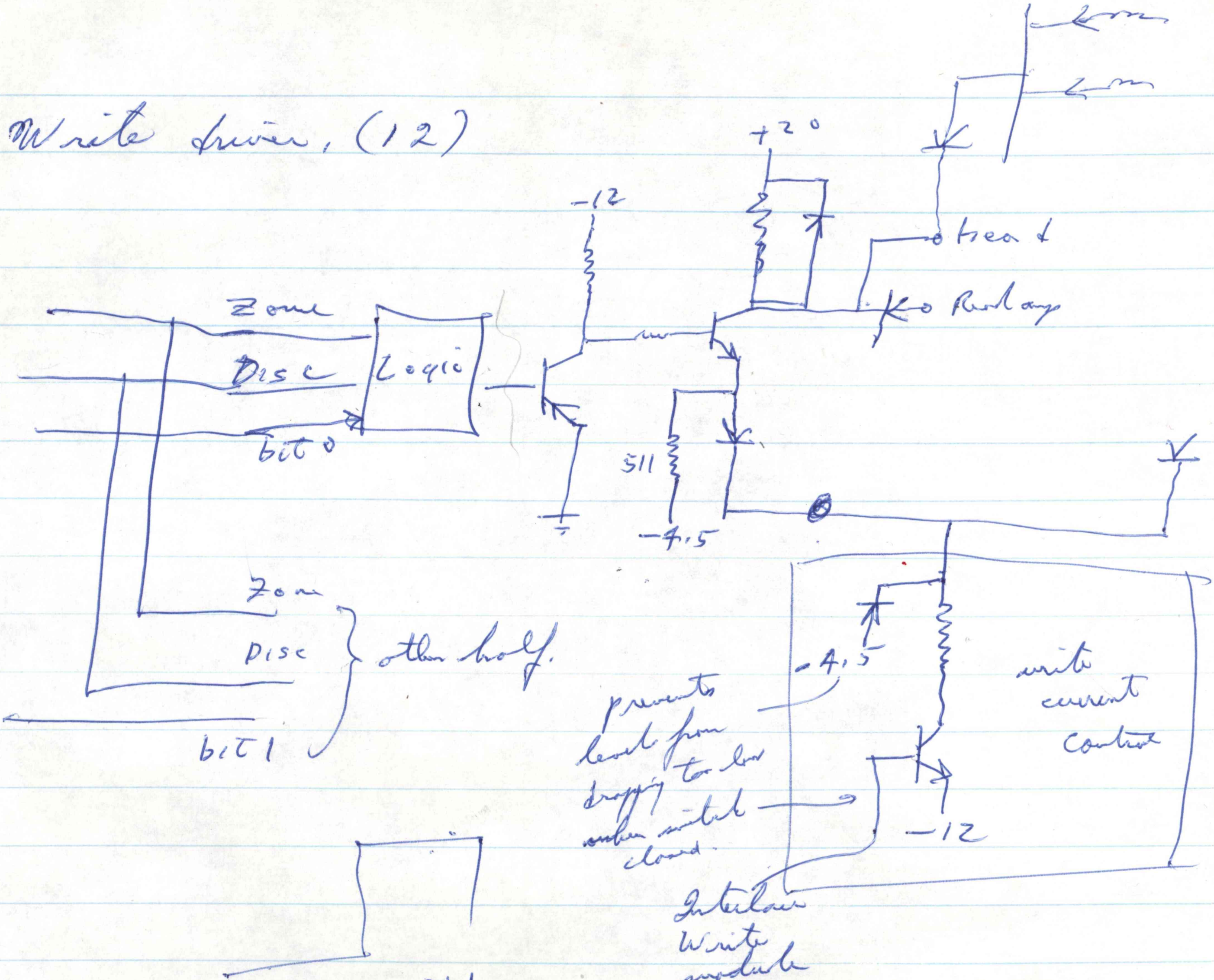


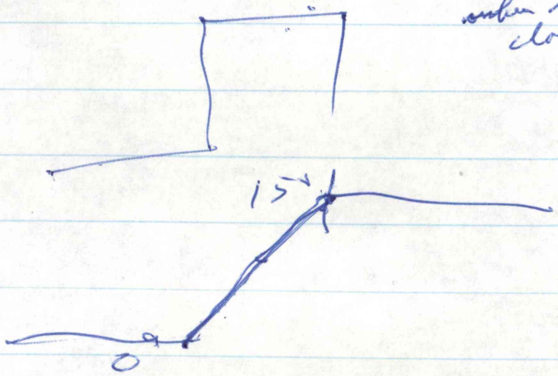
12 center taps are all common
can get down to 6 by drilling board between holes



C boards

Write driver, (12)





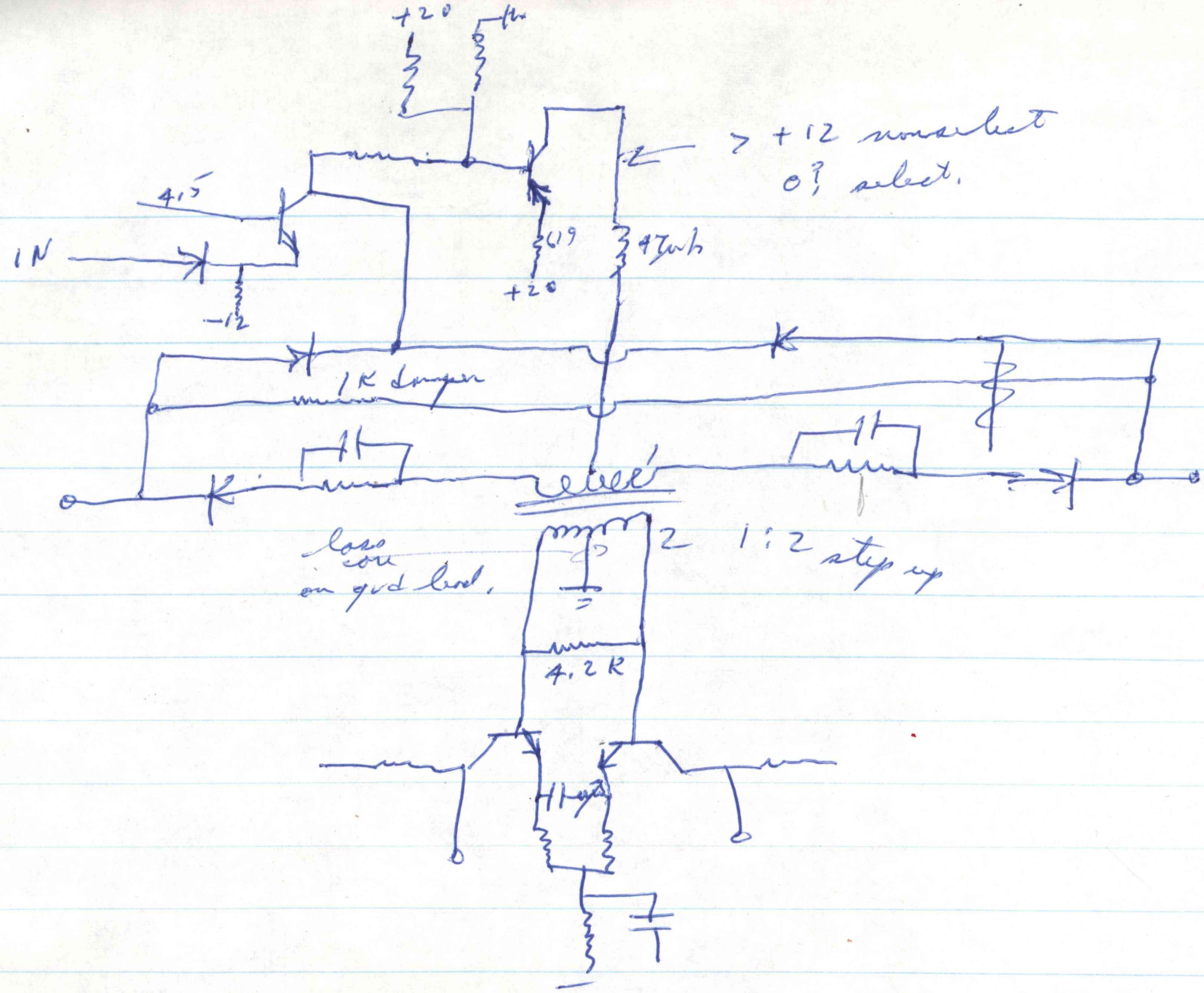
$$e = L \frac{I}{t}$$

Both on for read
0 + 1

& F/F drive for write operation

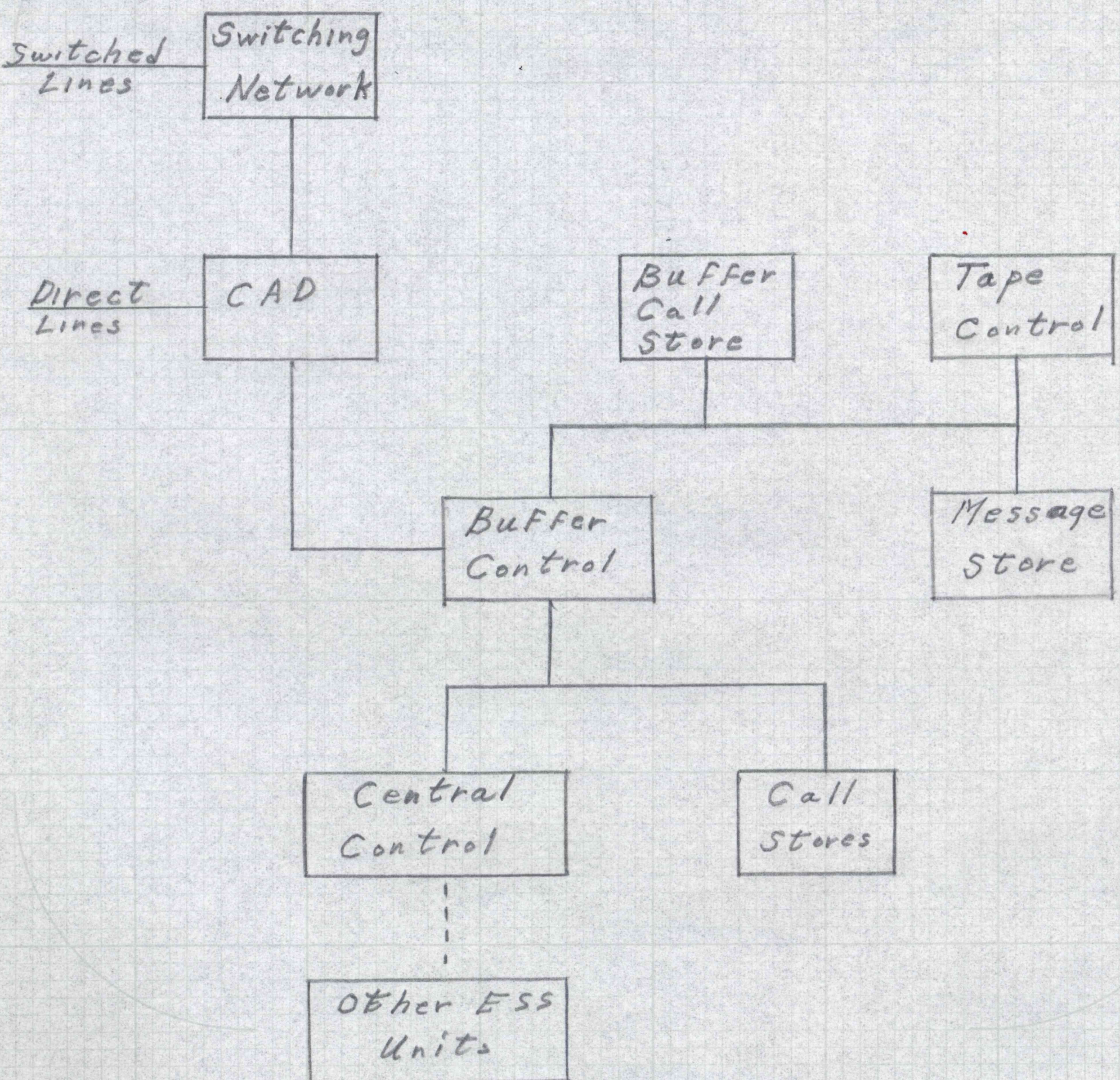
$$T = \frac{10 \times .15}{10}$$

$= .15$ μsec


+20
+12 nonselect
0? select.
4.5
IN
-12
619
+20
47uh
1K damper
lose
ccu
on gnd lead.
1:2 step up
4.2K

$7\frac{11}{16}$

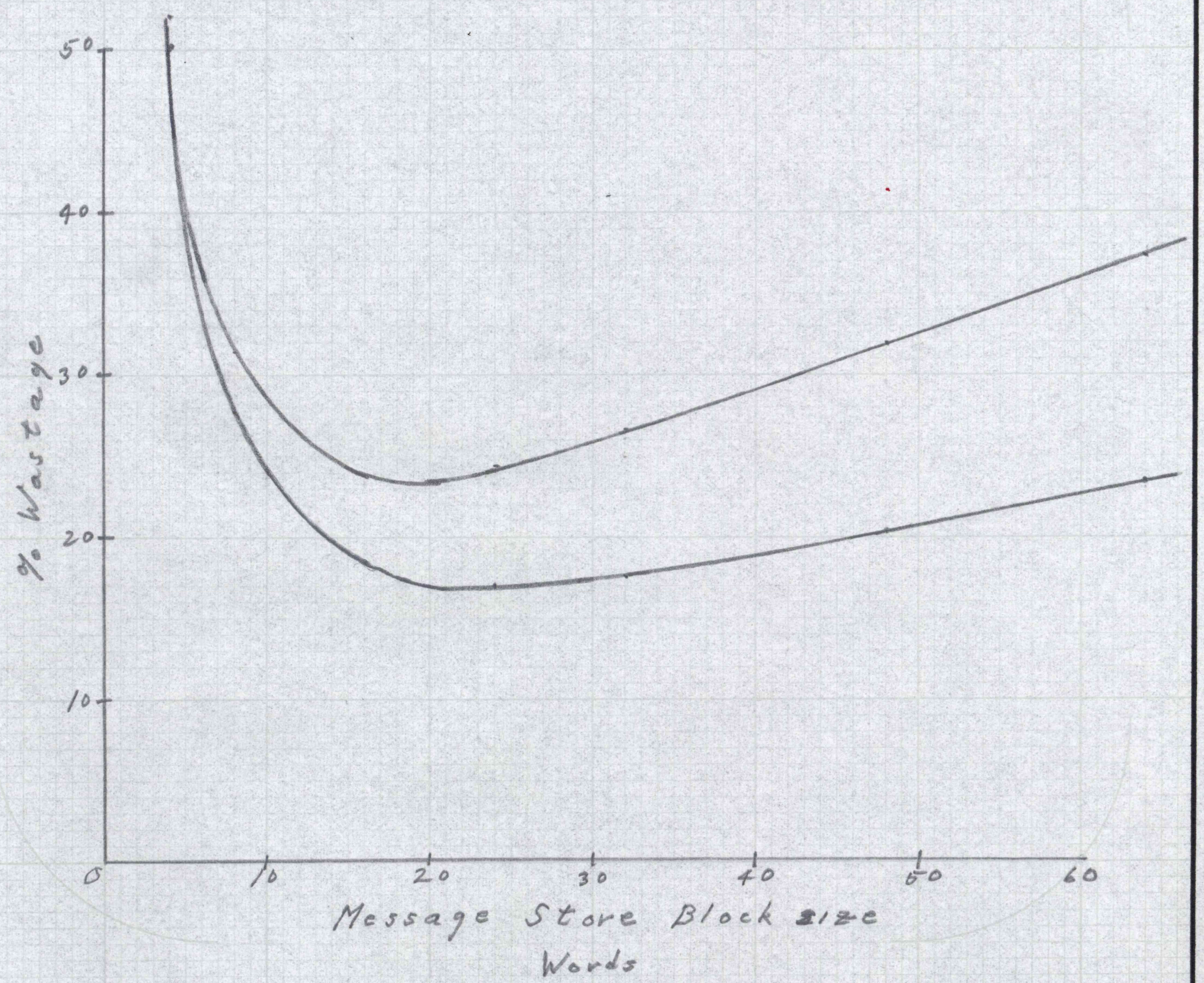
$10\frac{5}{8}$



ISSUE Fig 1	ENGR LEG DRAWN	TITLE Block Diagram DAC System	BELL TELEPHONE LABORATORIES INCORPORATED SHEET NO. OF SHEETS PER SET

ISSUE

PRINTED IN U.S.A.
E-1812-A-1 (1-61)



ISSUE	ENGR	TITLE	BELL TELEPHONE LABORATORIES INCORPORATED
Fig 2	LEG	Waste as a Function of Block Size	SHEET
	DRAWN		NO. OF SHEETS PER SET

206.0
55.65
261.65
2
523 30

1144
38.05
15245
2
30.490

79.2 1
36.8
116.0
2
23.2

18.93
4
7572
40.4
11612
23.22

79.8
45.25
12505
25.1

9428
52.97
147.25
2
29.4.5

10972
59.23
16895
2
33790

7 11/16

10 5/8

EVEN	ODD
2 No OP	1 No OP
0 NO-OP	27 No-OP
26	25 No-OP
20	23
18	17
10	15
Block 8	Block 11
BCSBS	BCSBS
Block 4 MSTA	Block 9 MSTA

↑

Start

MSTA - Message Store Track Address

BCSBC - Buffer Call Store Block Start Address

ISSUE

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E-1812-A-1 (1-61)

ISSUE	ENGR / DRAWN	TITLE	BELL TELEPHONE LABORATORIES INCORPORATED
Fig 3		Possible set of orders in BCS Queues	SHEET / NO. OF SHEETS PER SET

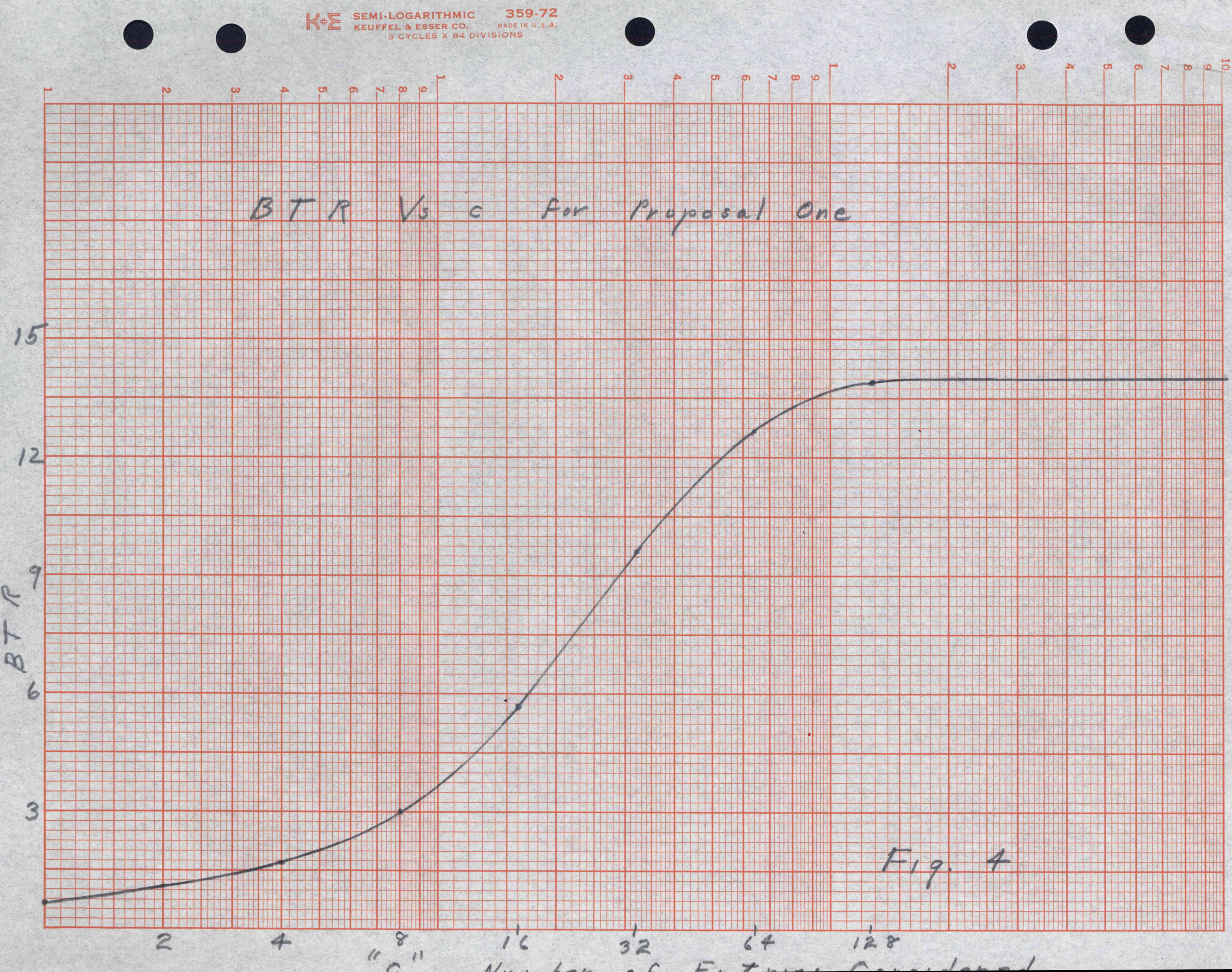
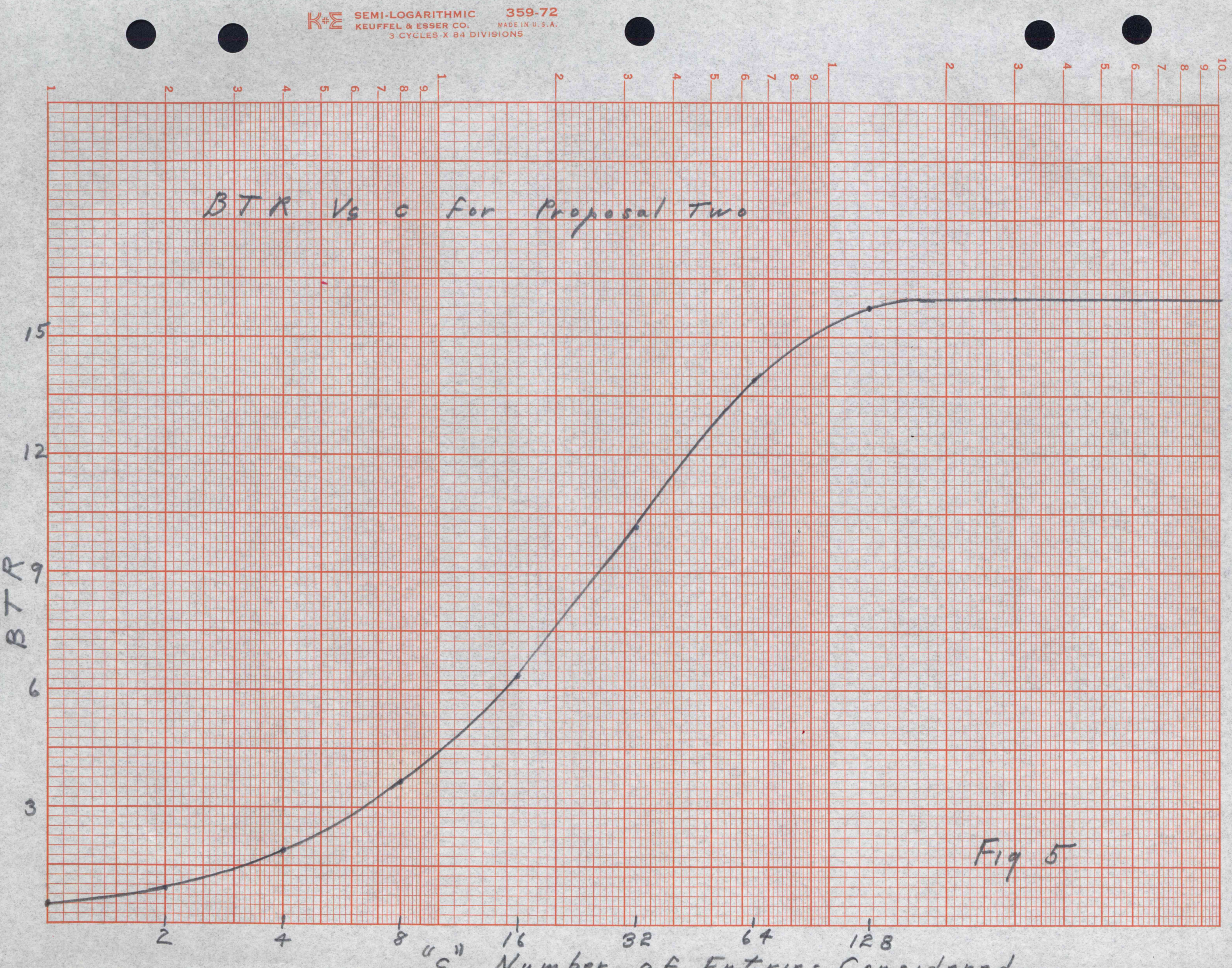

K+E SEMI-LOGARITHMIC 359-72
KEUFFEL & ESSER CO. MADE IN U.S.A.
3 CYCLES X 84 DIVISIONS
BTR Vs c for Proposal One
BTR
15
12
9
6
3
2
4
8
16
32
64
128
"c" Number of Entries Considered

Fig. 4


BTR Vs c for Proposal Two
BTR
15
12
9
6
3
2
4
8
16
32
64
128
"c" Number of Entries Considered
Fig 5
SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
3 CYCLES X 84 DIVISIONS
359-72
MADE IN U.S.A.

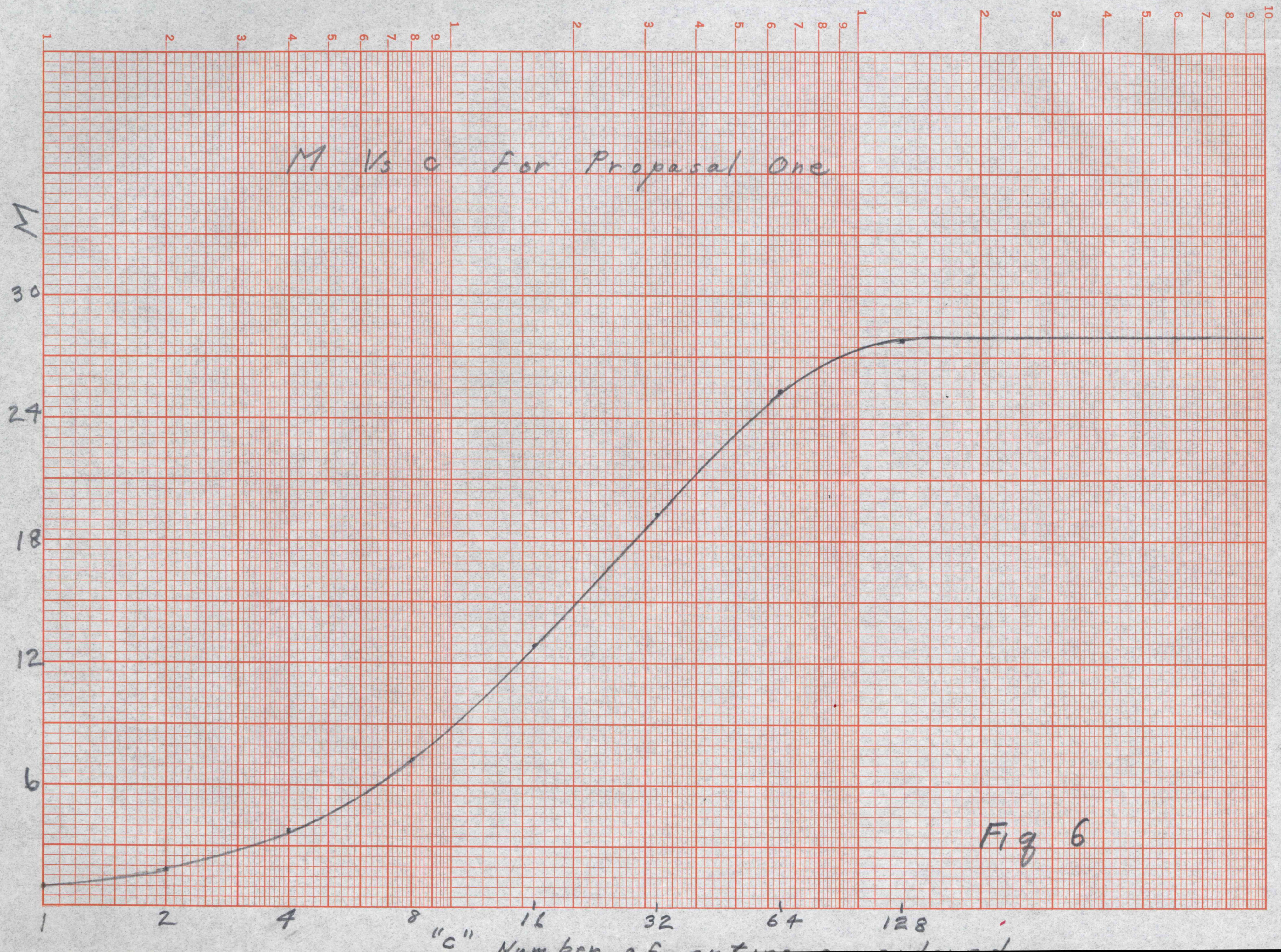
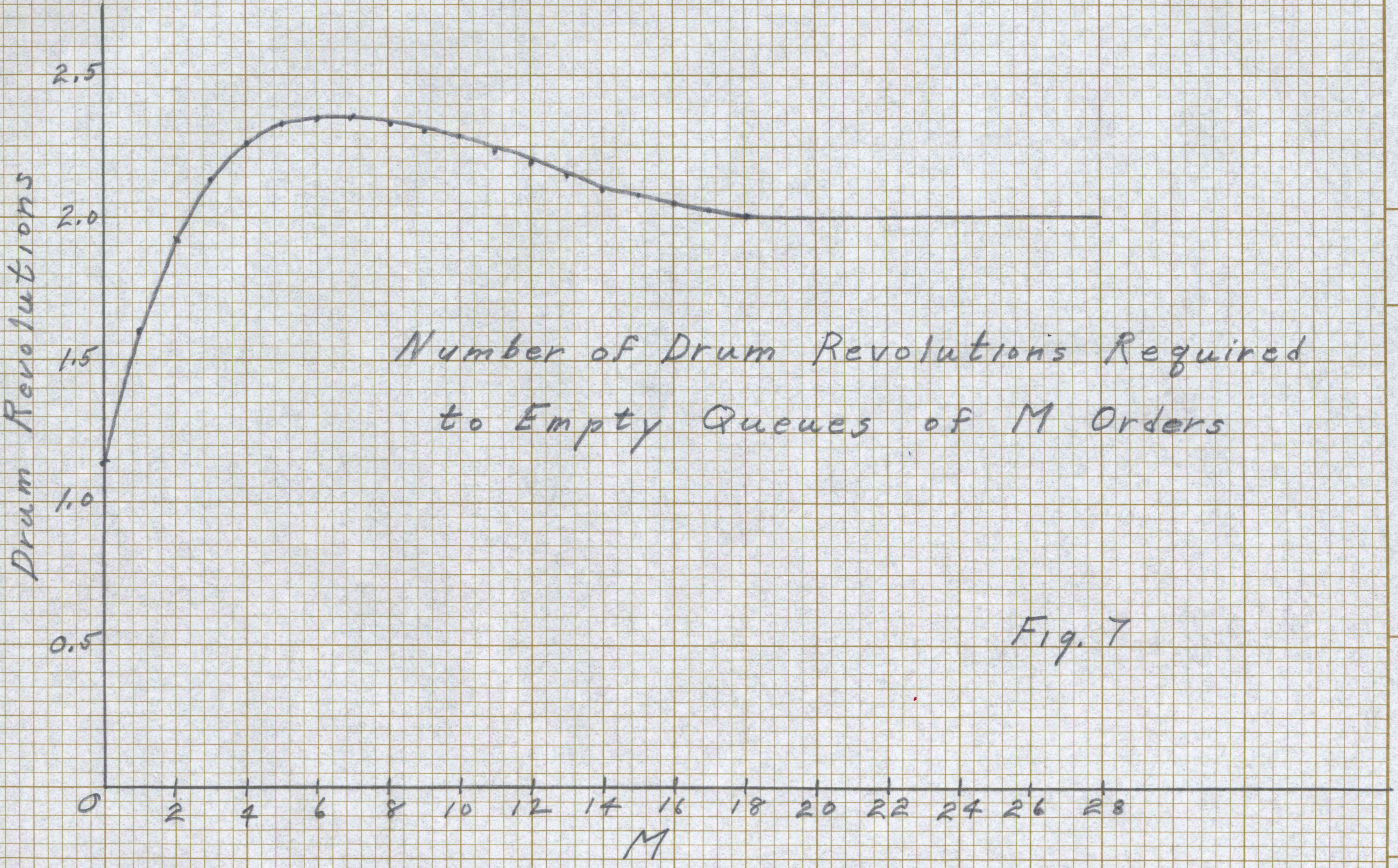


Fig 6

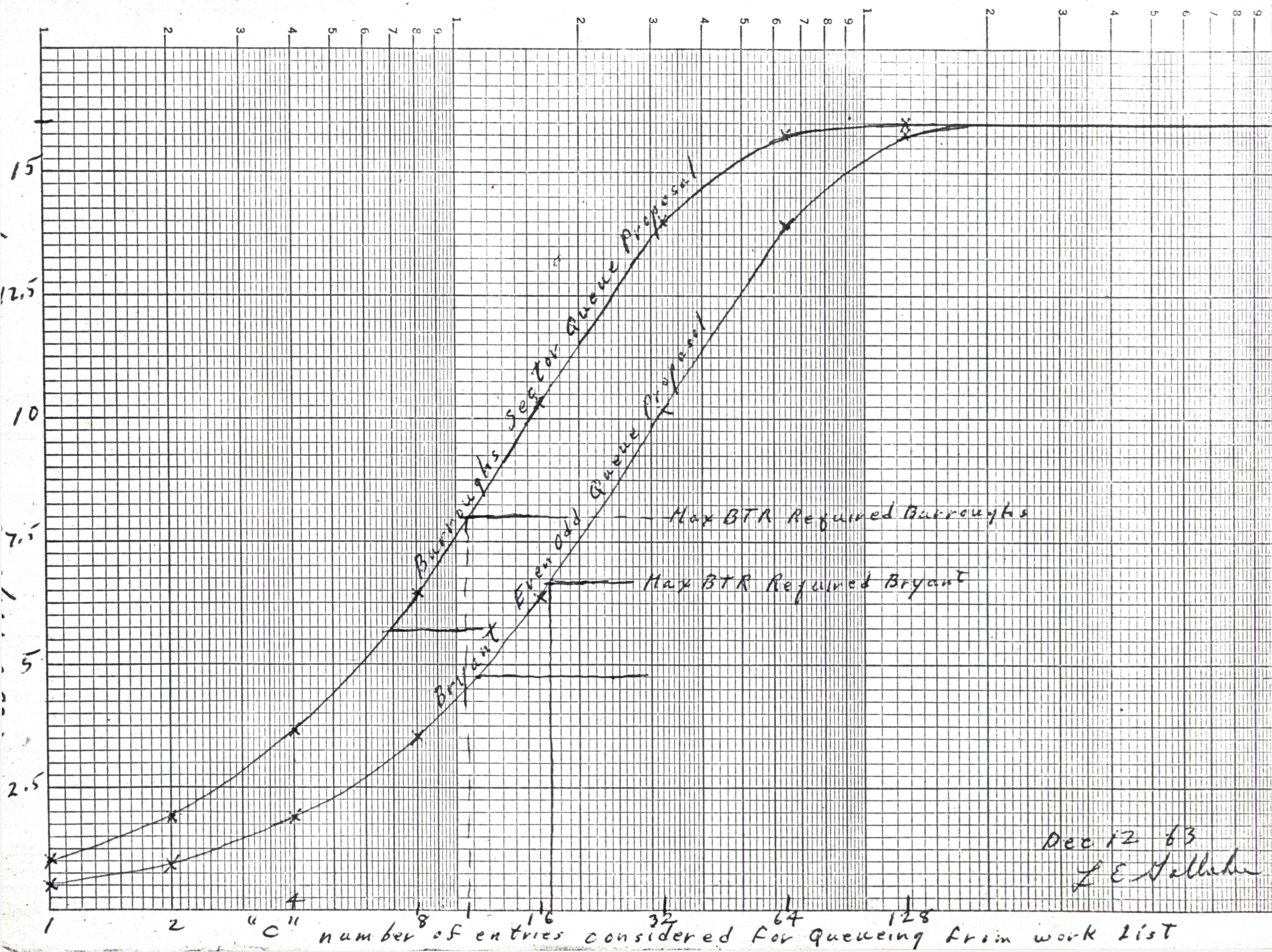


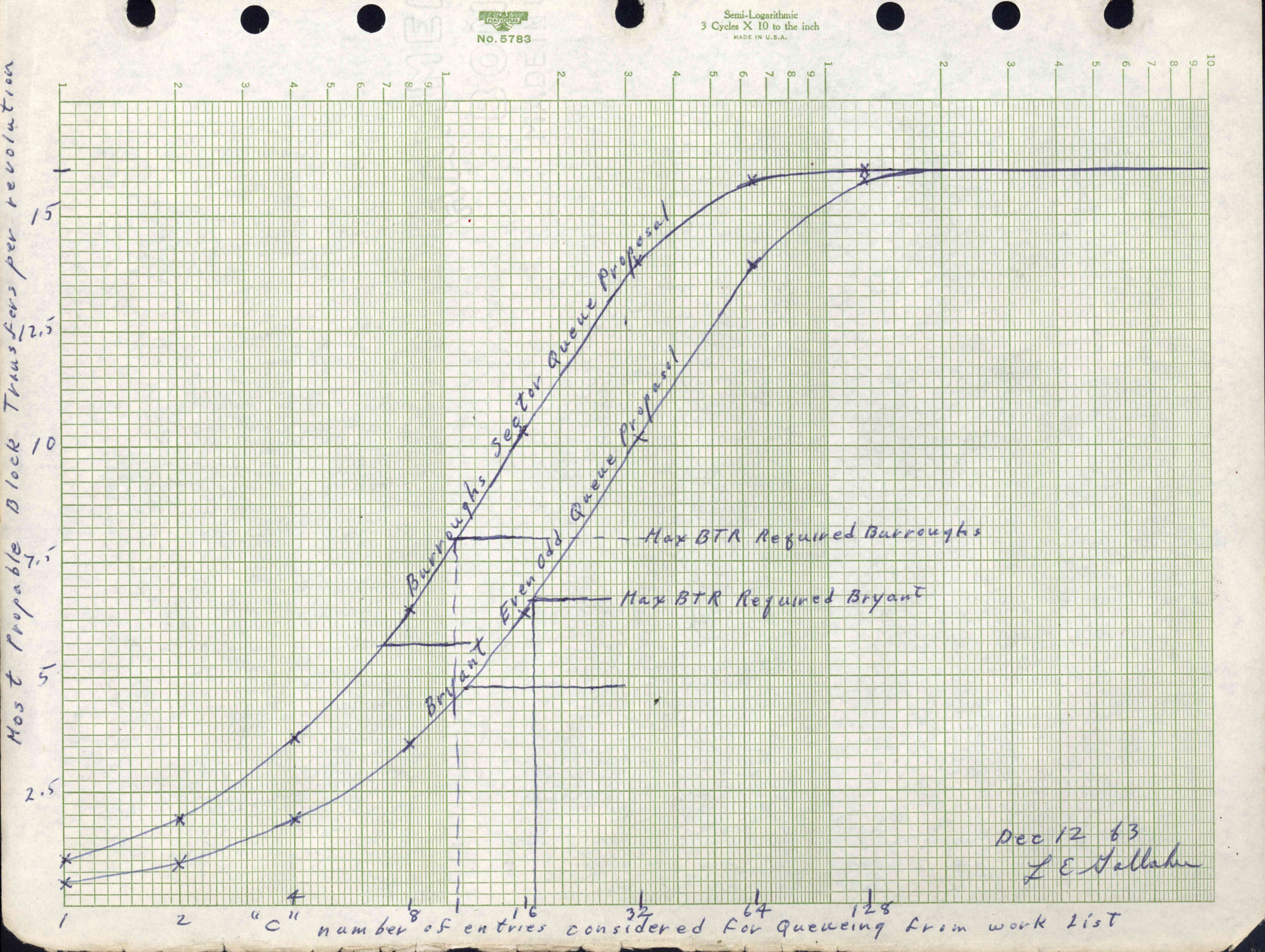
Number of Drum Revolutions Required to Empty Queues of M Orders

Fig. 7

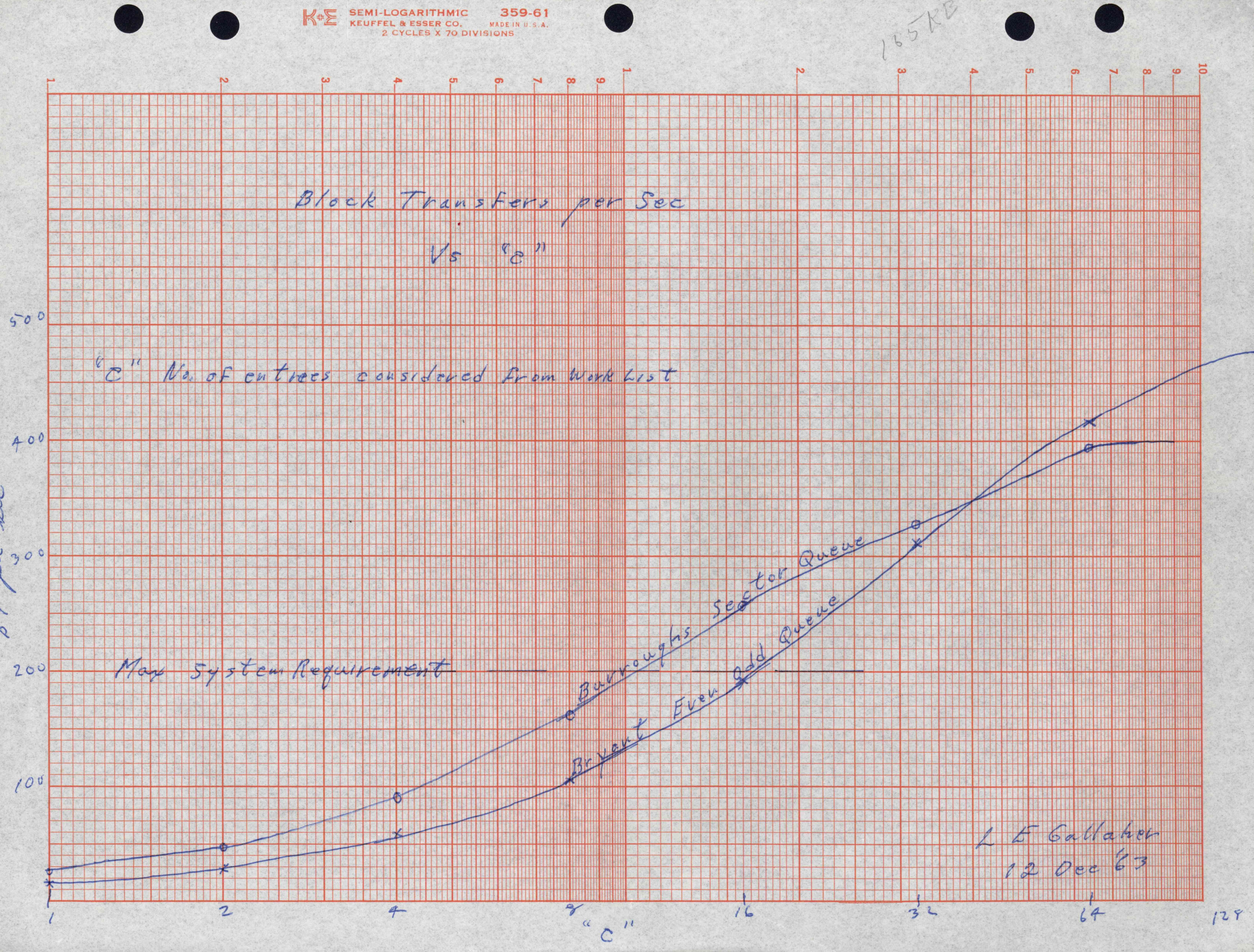
No. 5783

Semi-Logarithmic
3 Cycles X 10 to the inch
MADE IN U.S.A.





No. 5783
Semi-Logarithmic
3 Cycles X 10 to the inch
MADE IN U.S.A.
Most Probable Block Transfers per revolution
15
12.5
10
7.5
5
2.5
1
2
4
8
16
32
64
128
"C" number of entries considered for Queueing from work list
Burroughs Sector Queue Proposal
Bryant Even odd Queue Proposal
Max BTR Required Burroughs
Max BTR Required Bryant
Dec 12 63
L E Gallaher


K+E SEMI-LOGARITHMIC 359-61
KEUFFEL & ESSER CO. MADE IN U.S.A.
2 CYCLES X 70 DIVISIONS
165KB
Block Transfers per Sec
Vs "c"
"C" No. of entries considered from Work List
Max System Requirement
Burroughs Sector Queue
Bryant Even Odd Queue
L E Gallaher
12 Dec 63
BT per sec
500
400
300
200
100
1
2
4
8
16
32
64
128
"C"

16 (1 − (~~16~~ 15

$16\left(1-\left(\frac{15}{16}\right)^2\right.$

1089

2290) 2497
2290
20700
18320
20800
20610

1.089 bits/sec

718
1089) 7800
7623
1770
1089
6810
6534
109

13
5
65
65
71.5

2089 × 4/3

2783
3) 8328

1089 × 4/3
1452
3) 4356

1815
1089 × 5/3
6) 1089

48 ×	6	Track
12	~~4~~	Block #
16 ×	4	Sector
8	3	DF

26
32
52

78
832
3
2496

.2 = 2494 / 2290

1.45

~~4416×4~~
832
4
3328 .2 = 3326 / 2290

1.82

832
4
4160 .2 = 4158 / 2290

832
64
768

32
24
128
64

~~16~~
48
16

256
3
768
96

76800
3072
73728
768
589824
442368
516096
56,683,104

27%

73,728 Blocks. each block contain

32 memory words.

.57 Teletype words. 64 characters.

$\frac{64}{6}$ words.

$\frac{570,000}{250}$

$\frac{32}{3} \times .73 = 7.8$ words.

2,000

Probability Calculation for 9 of 16

$$MPN_{zeroes} = 16 \times \left(\frac{15}{16}\right)^n$$

$$BTR = \frac{16 - MPN_0}{2}$$

~~For 17~~ $\log_{10} 16 = 1.20412$

$\log_{10} 15 = 1.17609$

$.02803$

For word list considered

$= 128$ $128 \times .02803 = 3.59$

antilog $= 3890$

$MPN_0 = \frac{16}{3890} = .0041$

$BTR = \frac{16 - .004}{2} = 15.996$

$= 64$ $64 \times .02803 = 1.794$

antilog $= 62.23$

$MPN_0 = \frac{16}{62.23} = .258$

$BTR = 15.74$

$= 32$ $32 \times .02803 = .897$ $.89696$

antilog $= 7.8886$

$MPN_0 = \frac{16}{7.89} = 2.02$

$BTR = 13.98$

$= 16$ $16 \times \_\_\_ = .449$ $.44848$

antilog $= \cancel{2.812}$ 2.8085

$MPN_0 = \frac{16}{2.8085} = 5.69$

$BTR = 10.31$

$= 8$ $8 \times \_\_\_ = .22424$

antilog $= 1.6759$

MPN_0 $16/1.6759 = 9.55$

$BTR = 6.45$

4 $.02803 \times 4 = .11212$

1.2946

$MPN_0 \frac{16}{1.2946} = 12.35$

$BTR = 3.65$

2 $— \times 2 = .05606$

1.1378

$MPN_0 \frac{16}{1.1378} = 14.1$

$BTR = 1.9$

1 antilog $= 1.0667$

$MPN_0 = \frac{16}{1.0667} = 15$

$BTR = 1.0$

Probability Calculations for Q of 32
Odd Q of 16 + Even Q of 16

$$MPN \text{ of zeros} = 32 \times \left(\frac{31}{32}\right)^n$$

$\log_{10} 32 = 1.50515$
$\log 31 = 1.49136$
$= 0.01379$

for 128 list

~~MPN = 32 X~~

$.01379 \times 128 = 1.762$

anti log = 57.81

$MPN_0 = \frac{32}{57.81} = .55$

$BTR = \frac{32 - .55}{2} = 15.72$

For 64 $\quad .01379 \times 64 = .881$

anti log = 7.603

$MPN_0 \quad \frac{32}{7.603} = 4.2$

$BTR = \frac{32 - 4.2}{2} = 13.9$

For 32 $\quad = .441$

antilog = 2.76

$MPN_0 = \frac{32}{2.76} = 11.6$

$BTR = \frac{32 - 11.6}{2} = 10.2$

for 16 $\quad = .2205$

antilog 1.6605

$MPN_0 = \frac{32}{1.6605} = 19.26$ $\quad$ 1277

$BTR = \frac{32 - 19.26}{2} = 6.37$

8 $.01379 \times 8$ $.11032$

actly 1.2892

MPNO $\frac{32}{1.2892} = 24.82$ 7.18

BTR $= \frac{32 - 24.82}{2} = 3.56$

4 $.05516$

1.1354

MPNO $\frac{32}{1.1354} = 28.18$

BTR $= 1.96$ 3.82

2 $.02758$

1.0656

MPNO $= \frac{32}{1.0656} = 30.02$

BTR $= .99$

1 BTR $= .50$

check 1.0323

$\frac{32}{1.0323} = 31$

OK